Below Terrace Reservoir, water quality has improved significantly following remediation activities at Summitville. However, elevated concentrations of metals during spring and other times may be related to resuspension of reservoir sediments. Alternatives should be considered to reduce the resuspension of sediments in Terrace Reservoir.

Although average water quality has returned to levels similar to estimates of pre–open pit mining water quality, future water quality is dependent on the operation of the SDI and water treatment plant at Summitville. Unfortunately, the risk of untreated releases from the site and the SDI remains high, and untreated releases have the potential to kill fish populations restored to the Alamosa River downstream of Wightman Fork and impact downstream water users. Efforts should be continued to fund the installation of a new treatment plant with both a higher treatment efficiency and capacity and increase the capacity of the SDI. A remediation alternative should also be considered to buffer the effects of potential untreated releases.

Loads from historic mines are less significant on a watershed scale than loads from the Summitville site and from natural sources. However, inactive mines have significant local impacts and may be opportune points for treatment to reduce contamination in the Alamosa River.

The water of the Alamosa River is often observed to be turbid. Levels of suspended sediments rise exponentially during spring snow melt and precipitation effects. It is anticipated that levels of suspended sediments produced during storm events may be a significant risk to fish populations that may be restored in the Alamosa River. In order to restore a viable fish population, remediation alternatives to reduce suspended sediments should be considered.

2.5 Ground Water

Mining, agriculture, and other human activities may have impacted ground water quantity and quality in the Alamosa River watershed. Reduced ground water quantities and impaired water quality are evident in the alluvial valley near Capulin, Colorado. This section provides information on the current status of ground water quantity and quality, as well as specific impacts related declining ground water levels. Detailed ground water monitoring data and documented changes in water levels within the valley are lacking. Additional data collection is necessary to quantify ground water changes and develop an accurate assessment of cause and effect.

2.5.1 Ground Water Sources

The San Luis Valley is a primary feature of the Rio Grande watershed and is defined by the areal extent of Tertiary and Quaternary fill deposits. The aquifer system consists of hydraulically interconnected Rio Grande River alluvium and underlying basin–fill deposits. The thickness of the basin–fill deposits in the San Luis Valley is estimated to be as much as 30,000 feet (CGS, 2003). The two main hydrogeologic features are the upper unconfined and lower confined aquifers. The confining layer which separates the two main aquifers is composed of interbeds of clay within the Upper Alamosa Formation (CGS, 2003).

The Alamosa River watershed study area lies along the margin of the southwest portion of the San Luis Valley. Along the edge of the San Luis Valley, the boundary between the unconfined and confined aquifers is poorly defined. The unconfined aquifer is the source for most of the domestic water wells around the Capulin area, and is therefore the subject of this discussion.

Figure 2–74 presents a hydrogeologic stratigraphic column of the San Luis Valley, which was prepared by HRS Consultants, Inc. in association with the Rio Grande Decision Support System (RGDSS) (the RGDSS is described in more detail in **Section 2.5.3**). As shown on **Figure 2–74,** the uppermost units coincide with the unconfined aquifer, which consists of well sorted to poorly sorted sands, silts, and gravels, and Eolian sands. These alluvial deposits consist of poorly sorted, rounded to sub–angular gravels, sands and silts. The alluvial material of the unconfined aquifer is underlain by the Alamosa Formation which consists of interbedded blue, gray, and green clays and dark sands. The depth to confining clay varies from approximately 100 feet in the northern part of the basin to 40 feet in the southern part of the Alamosa River Basin in Conejos County (CGS, 2003).

It is estimated that the unconfined aquifer has transmissivities ranging from 5,000 to 225,000 gallons per day per foot (gpd/ft) throughout the entire valley. As presented in **Figure 2–75**, transmissivities in the Capulin area range from 5,000 to 15,000 gpd/ft. In general, the proximal portion of an alluvial fan, near the base of the mountains, is comprised of coarser material than the distal portion. Transmissivities are typically greater at the proximal portion, or head, of an alluvial fan and diminish downgradient as sediment size decreases. Therefore, greater surface water loss to the unconfined aquifer can be expected near the head of the alluvial fan, where the Alamosa River exits the bedrock canyon.

The principal components of ground water recharge in the San Luis Valley are mountain front recharge, precipitation, irrigation return flow, streambed infiltration, and ground water inflow from adjacent bedrock aquifers. The bedrock aquifers along the mountains bounding the San Luis Valley are recharged by precipitation and snowmelt. These aquifers discharge to the basin–fill aquifers through ground water inflow along the mountain front, or contribute to base flow in the mountain streams that eventually seep into the basin–fill aquifers. Recharge to aquifers in the western portion of the San Luis Valley is primarily through ground water inflow from the permeable volcanic rocks of the San Juan Mountains. Inflow from these bedrock aquifers is approximately 100,000 to 200,000 acre–feet per year, through the Conejos Formation (CGS, 2003).

As shown on the potentiometric surface map presented on **Figure 2–76,** the general direction of ground water flow in this region is towards the center of the valley. Ground water moves out of the basin through evapotranspiration, well pumping, discharge to streamflow, and underflow to New Mexico (CGS, 2003). Due to the large amount of water pumped from the unconfined aquifer for irrigation purposes in this area, ground water loss by well pumping is substantial. There is no effective ground water barrier in the southern portion of the valley. However, natural ground water movement is very slow due to low hydraulic gradients in that area (CGS, 2003). Ground water in the study area near Capulin flows downgradient following the Alamosa River toward La Jara and then south, towards the Rio Grande.

Figure 2–74. Hydrogeologic Units of the San Luis Valley

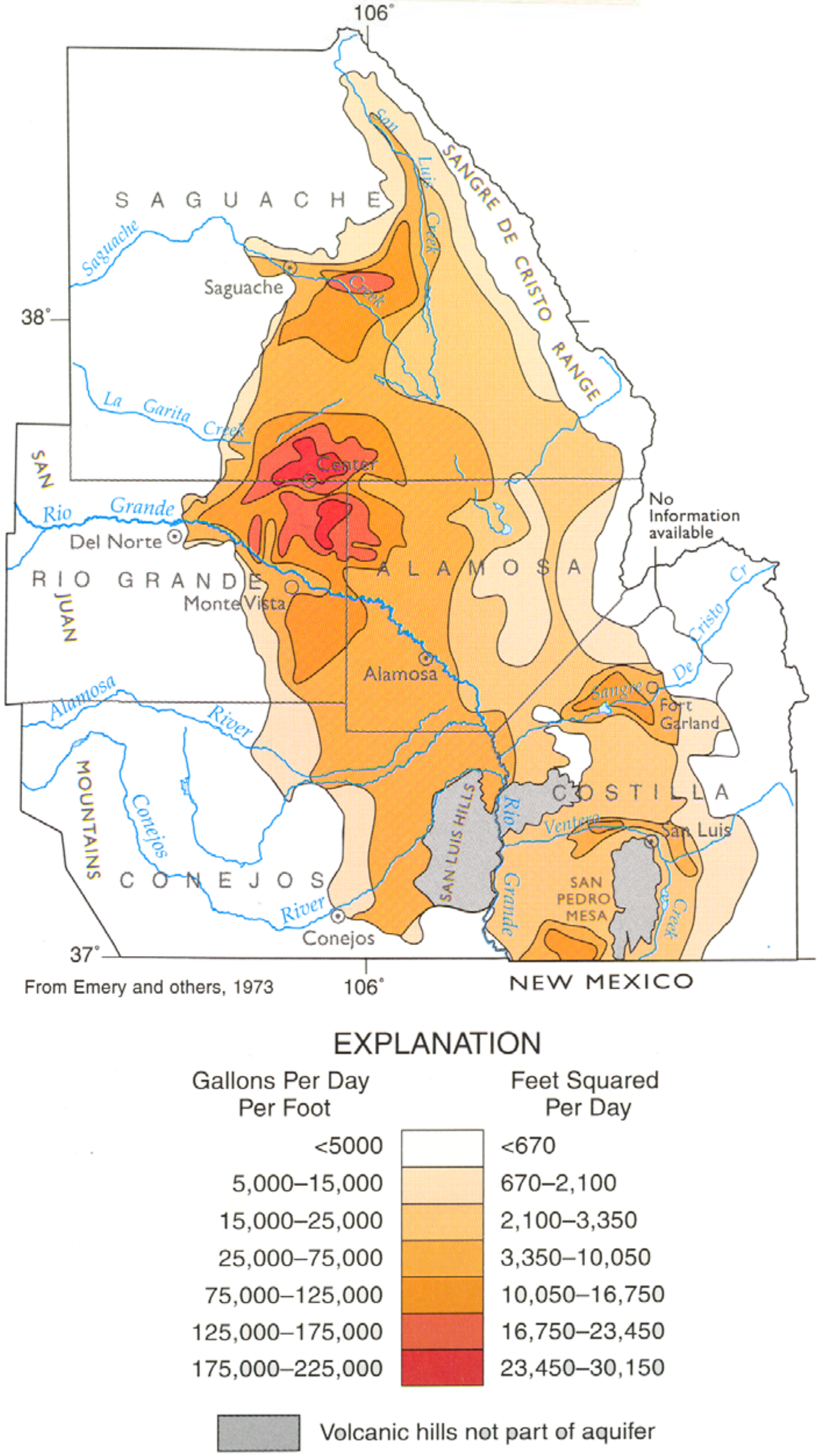
Era	System	Series	Stratigraphic Unit	Physical Characteristics	Hydrogeologic Unit	Saturated thickness (feet)
Cenozoic	Quaternary	Holocene	Stream deposits	Well to poorly sorted, uncemented, sands, silts, and gravels	Qal	
			Eolian sands	Well-rounded sands forming active and stabilized dunes	Unconfined aquifer (HRS unit 1): Qs	
			Alluvial fan 4	Poorly sorted, rounded to sub-angular gravels, sands, and silts; forms small, steeply-sided undissected alluvial fans, standing at modern stream level; found only as small cones at the mouths of small canyons and at the toes of older alluvial fans	Qf_4	0-100
		Pleistocene	Alluvial fan 3	Poorly sorted, rounded to sub-angular gravels, sands, and silts; forms large gently sloped relatively undissected alluvial fans, standing (8–12 feet) above modern stream level	Qf_3	0-100
			Alluvial fan 2	Poorly sorted, rounded to sub-angular gravels, sands, and silts, forming large intermediate-sloped moderately dissected alluvial fans, standing (40 feet) above modern stream levels	Qf_2	0-100
			Alluvial fan 1	Poorly sorted, rounded to sub-angular gravels, sands, and silts, forming large steeply sloped strongly dissected alluvial fans, standing (60–90 feet) above modern stream level; characterized by a caliche layer near upper fan surface	Qf_1	0-100
			Alamosa Formation	Interbedded, discontinous, blue, gray, and green clays and dark sands; sands are dominantly fine-grained; uppermost clay layers divide valley into an upper unconfined aquifer and lower confined aquifers; 0–20,000 feet	HRS unit 2	0–200
	Tertiary	Pliocene	Vallejo-Santa Fe Formation	Red to maroon shales, siltstones, and poorly sorted sandstones and conglomerates, with interbedded volcanic flows of the San Juan Mountains; top of the unit is dominantly conglomerates and sandstones, while bottom is dominantly siltstones and shales; deposits are cross-bedded and channel cut; Oligocene sills are found in section	Confined aquifer: HRS unit 3	4,050–14,500
		Miocene				
Precambrian			Crystalline rocks	Granite, gneiss, and schist		

Source: Modified form Ground Water Atlas of Colorado,

Colorado Geological Survey 2003

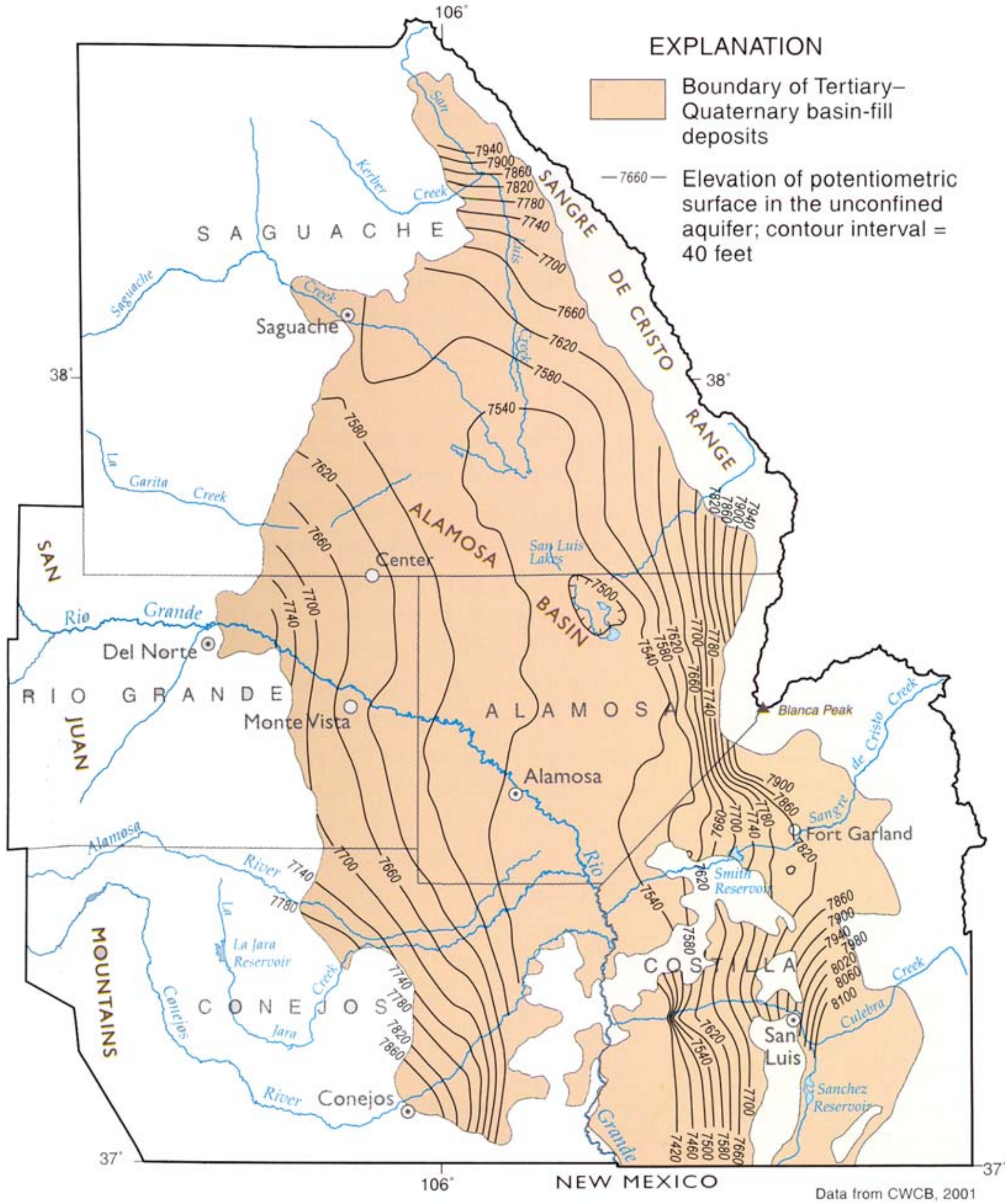
After HRS Consultants, 2001 and D. Huntley, 1976.

Figure 2–75. Transmissivity of the Unconfined Aquifer, San Luis Valley



Source: Ground Water Atlas of Colorado, Colorado Geological Survey 2003 (Edited)

Figure 2–76. Water Table of the Unconfined Aquifer of the San Luis Valley, Late 1996–Early 1997



Source: Ground Water Atlas of Colorado, Colorado Geological Survey 2003 (Edited)

2.5.2 Ground Water Use

The alluvial valley of the Alamosa River watershed is dominated by agricultural land use which relies heavily on both surface and ground water. The vast majority of wells in the study area are private wells used for domestic drinking water and irrigation.

Due to the hydrologic connection between surface water and the confined and unconfined aquifers, the Colorado State Engineer's Office has restricted irrigation well drilling (CGS, 2003). A review of well records in the Denver office of the CDWR was completed to determine any trends in ground water elevations for potentially unconfined wells in the study area. The results of this review are presented in **Table 2-21**. The average yield of the wells studied was 15 gpm, which is the statuatory limit for domestic use production. Most of these wells were completed to depths ranging from 50 to 109 feet. The screened intervals and ground water elevations indicate that the main water bearing zones are deeper in the south central portion of the watershed, which coincides with the potentiometric surface map presented on **Figure 2–76**.

Table 2-21. Selected Wells in the Alamosa River Watershed

Permit No.	Location	Well Owner	Completion Date	Yield[1] (gpm)	Total Depth (ft)	Screened Interval	Static Level	Pumping Level	Ground Elevation[2]	Static Water Elevation[3]	Main Water Bearing Zone
118673	SESW S29 T37 R5	Anthony, Luke	1981	15	109	94–109	85	97	9114	9029	Sand & Gravel
203037	SESW S29 T37 R5	Wilkins, Fred	1998	15	65	60–65	24	30	9080	9056	Sand & Gravel
15828	SWSW S10 T36 R5	Kincannon, Ray	1963	dry	88	Not cased			9320		Clay & Boulders
31454			1967		49	39–49			8960		Sand & Gravel
32521			1971	15	63	53–63					Clay & Sand
60413–A	SWSE S29 T36 R7	Nusz, William A.	2002	5.5	84	60–84	32	80	8226	8194	Clay, Sand & Gravel
193094–A	SESE S29 T36 R7	Nusz, William A.	1997	15	68	46–66	40	55	8210	8170	Sand & Gravel
88835	SWSW S7 T35 R8	Gomez, John	1977	15	84	74–84	60	68	7884	7824	Sand & Gravel
141009	NWSE S35 T36 R7	Garcia, Frank	1986	15	103	93–103	82	90	8040	7958	Sand & Gravel

Notes:
[1]Yield, Static Level, Pumping Level are as of the Completion Date.
[2]Ground Elevations are estimated using USGS quadrangle maps.
[3]Static Water Elevations are derived by subtracting the static level from the ground elevation.
Source: CDWR

2.5.3 Decline in Ground Water Levels

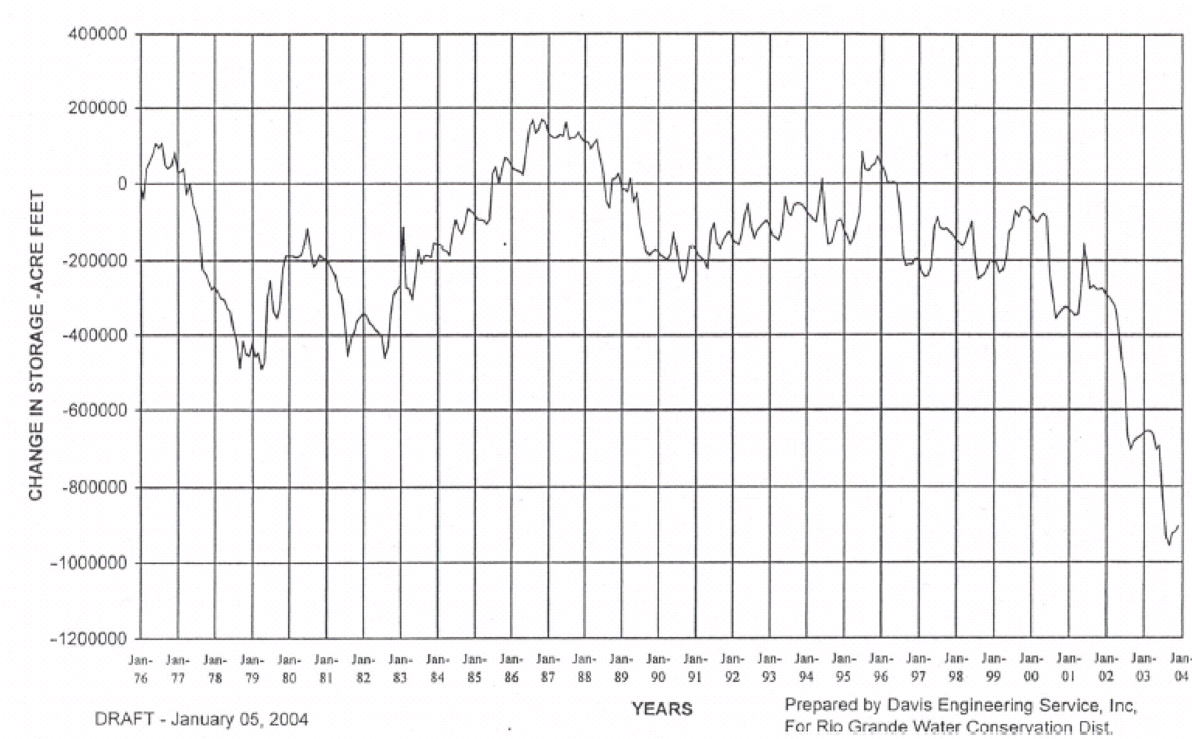
Currently, there is concern about the level of ground water in the Alamosa River watershed decreasing. One activity believed to have caused a decline in the ground water table is the channel straightening project completed in response to flood concerns in the 1970s (Hirsch, 2003). Major erosion, which was caused by eliminating meanders and increasing flow velocities, dropped the stream bed and may have locally lowered the water table in the lower watershed.

The recent drought has dictated additional scrutiny of the Alamosa River's interaction with the ground water table. Depending on local conditions at a specific reach, a river channel is either a losing stream, in which surface water recharges ground water, or a gaining stream, in which the ground water is lost to surface water. Downstream of Terrace Reservoir, the Alamosa River is generally considered a losing stream, which implies that surface water in the river typically recharges the unconfined aquifer. Due to the fact that precipitation and snowmelt are major sources of recharge for the alluvial aquifer, the recent drought is believed to have had an impact on ground water levels. In addition, there is local concern that the lack of instream flows has accentuated these perceived impacts on the ground water table. **Figure 2–77** presents a graph prepared by Davis Engineering Service, Inc. which depicts the fluctuations in unconfined aquifer storage in the west central portion of the San Luis Valley between 1976 and 2004. As shown on this graph, the volume of ground water stored in the unconfined aquifer has decreased drastically since 2001. While this information suggests that aquifer storage in some areas of the valley has declined, additional monitoring of aquifer storage in the study area near Capulin will be necessary to quantify the effect of the drought in the Alamosa River watershed.

The rate of water lost from the Alamosa River to ground water downstream of Terrace Reservoir can vary depending upon flow conditions. It is estimated that approximately 10 to 12 cfs is needed below the dam at Terrace Reservoir to ensure streamflow reaches Capulin under normal conditions (VSCC, 2003). Field data collection using flow nets and seepage meters would facilitate a quantitative analysis of water loss rates throughout the watershed. In addition, ground water modeling using software such as MODFLOW would be useful to gain a further understanding of the relationship between the Alamosa River and the ground water table and to determine return flows and seepage zones. MODFLOW simulates recharge, evapotranspiration, flow to wells and drains, and exchanges with rivers (Brown, 1995). An adequate understanding of these factors is necessary to quantify river gains or losses in each reach.

The RGDSS is a water management system being developed by the Colorado Water Conservation Board and CDWR. The Rio Grande Water Conservation District (RGWCD) maintains a water level database for the San Luis Valley, which was referenced to determine possible changes in ground water levels in the study area. While the number of monitoring wells in the basin is extensive, there are a very limited number of wells in the head of the alluvial fan and the vicinity of Capulin.

Figure 2–77. Decline in Water Levels in the San Luis Valley



Source: Davis Engineering Services, Inc.

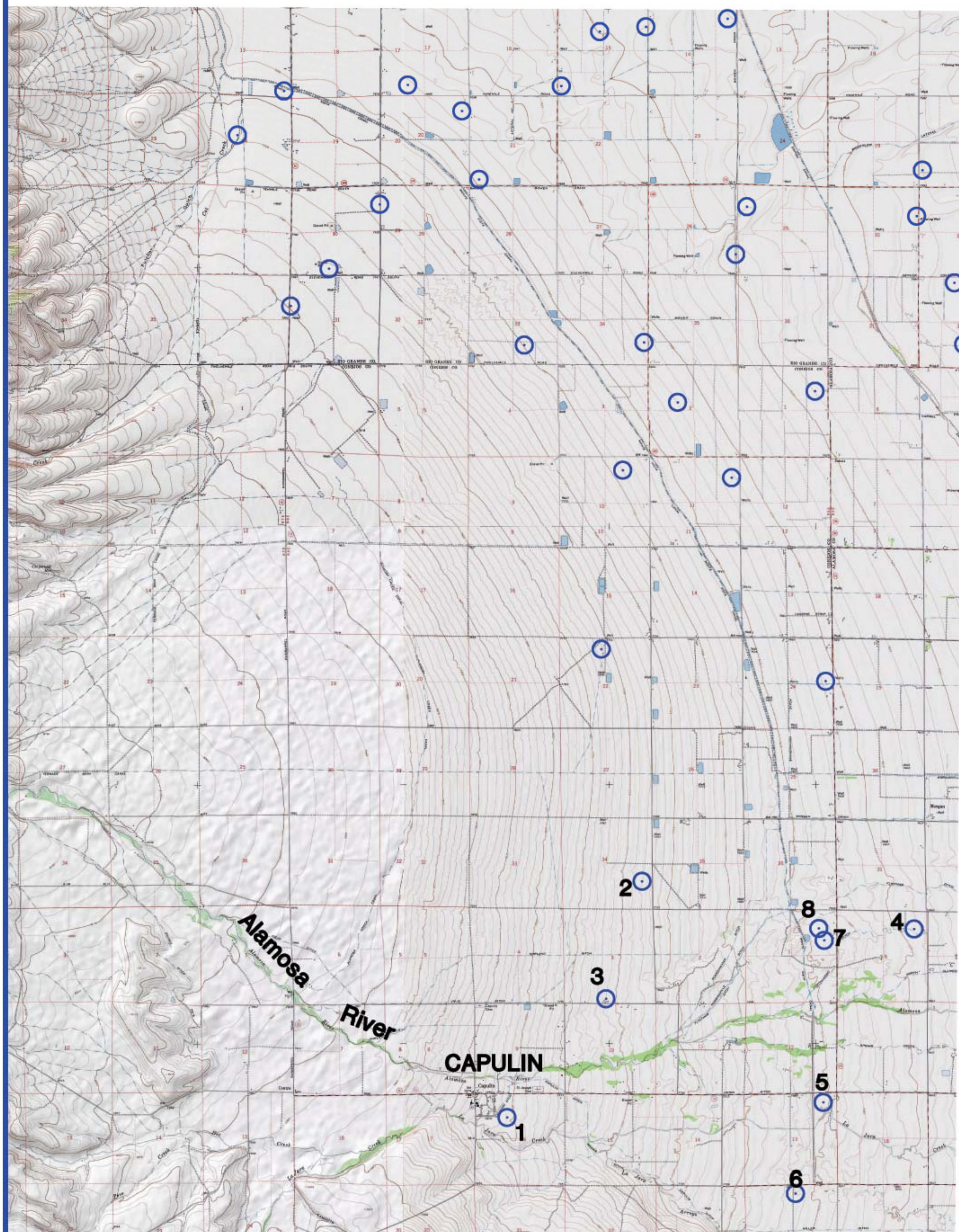
Table 2-22 presents a summary of available information on wells to the east of Capulin. The locations of these wells, relative to the Alamosa River and Capulin, are presented in **Figure 2–78.** The unconfined aquifer monitoring wells vary in depth from 22 to 45 feet. While only two of the unconfined wells shown in **Table 2-22** had data for recent years, both witnessed a sudden decrease in ground water levels after 2001. Overall, however, water levels in these two wells have remained fairly constant over the years. Due to the location of these wells and the fact that this decline was not seen until after 2001, it is most likely attributable to the drought, rather than the channel–straightening project. Water level monitoring data, such as that available for the area east of Capulin and other areas in the basin, is needed for the upper watershed and alluvial fan west of Capulin in order to accurately assess trends in ground water levels in the study area.

To further understand and quantify the extent of ground water decline in the lower watershed of the Alamosa River, a long term monitoring plan will be necessary. Wells in all portions of the watershed should be monitored. However, because of the limited amount of data currently available at the head of the alluvial fan west of Capulin in particular, this area should be the subject of additional scrutiny. Piezometers should be installed along the river at different depths to determine ground water discharge and recharge. This information will greatly assist in determining remedial actions to raise the ground water table.

Table 2-22. Selected RGDSS Wells in the Vicinity of Capulin, Colorado

Map No.[1]	Well ID	Data Source	Ground Elevation	Location	Total Depth (ft)	Aquifer Type	Primary Site Use	Depth to Water	Ground Water Elevation	Date of Measurement
1	NA03500816ABB01	USGS	7796	NWNWNE S16 T35 R8	30	Unconfined	Destroyed	20.39	7775.61	1968
								16.17	7779.83	1969
								20.95	7775.05	1969
2	NA03600835BCC01	USGS	7735		44.63	Unconfined	Observation	33.03	7701.97	1993
3	NA03500803DCB01	USGS	7754	NWSWSE S3 T35 R8	1044	Confined	Unused	65.70	7688.30	1969
								57.60	7696.40	1970
4	NA03500905BBB01[2]	USGS, CDWR, RGWCD	7640	NWNWNW S5 T35 R9	28	Unconfined	Observation	3.90	7636.15	1974
								3.23	7636.82	1975
								3.64	7636.41	1985
								2.91	7637.14	1995
								4.80	7635.25	2003
5	NA03500907CCC01[2]	USGS, CDWR	7672	SWSWSW S7 T35 R9	608	Confined	Withdrawal of Water	35.90	7636.10	1970
								46.88	7625.12	1983
								41.73	7630.27	1990
								57.29	7614.71	2000
								62.90	7609.10	2003
6	NA03500813DCD01[2]	USGS, CDWR	7677	SESWSE S13 T35 R8	22	Unconfined	Unused	4.42	NaN	1969
								6.34	NaN	1981
								4.91	NaN	1991
								5.12	NaN	2000
								9.73	NaN	2003
7	NA03600931CBC01[2]	USGS, CDWR	7668	SWNWSW S31 T36 R9	195	Confined	Withdrawal of Water	9.30	7658.70	1968
								10.00	7658.00	1980
								9.77	7658.23	1990
								8.98	7659.02	2000
								12.58	7655.42	2003
8	NA03600905BBB01	USGS	7664	NENENE S1 T35 R8	27	Unconfined	Unused	4.00	7660.00	1975

Notes:
[1]Refer to figure below for Well Locations.
[2]These wells have extensive data. For summary purposes, water depth entries have been condensed.
Source: RGWCD



Alamosa River Watershed Restoration Master Plan

MWH in association with Agro Engineering, Lidstone and Associates, Inc., and SWCA

Figure 2-78. RGDSS Model Target Well Location Map

Source; RGWCD (Edited)

2.5.4 Ground Water Quality

In recent years, several disturbances in the San Luis Valley have affected ground water quality. Agricultural land use has had a significant impact on water quality in the lower portion of the Alamosa River watershed. Evapotranspiration and leaching of salts caused by the recirculation of applied irrigation water has increased mineral content. Therefore, the salinity hazard in the unconfined aquifer is medium to very high (CGS, 2003). Elevated nitrate levels are also attributable to the impact of agriculture. Total dissolved solids, which tend to be higher in alluvial systems, range between 200 to 500 mg/L near Capulin.

Ground water in the Alamosa River watershed is naturally high in metal content. Iron, Alum, Jasper, and Burnt Creeks contribute significant amounts of natural contaminants. The Summitville Mine has significantly impacted baseline conditions in the Alamosa River (high metal concentrations and acidity) and created adverse environmental conditions which are much greater than those present in the natural environment (USGS, 2001). In the 1980s, heap leach processes associated with open pit mining resulted in acidic, mineral rich discharges into Wightman Fork above Terrace Reservoir. Processing solutions also leaked into the underlying ground water beneath the Heap Leach Pad (VSCC, 2003). Also, in 1997 untreated acid mine drainage was released directly into Wightman Fork due to heavy rains which created more runoff than the on–site water treatment plant was capable of handling (Stern, 1997).

In 1993, Ecology and Environment, Inc. performed a study to assess baseline conditions and determine if contamination from the mine has occurred in the aquifer. Of the 21 domestic wells sampled, three were upstream of Terrace Reservoir, and 18 were downstream. The results showed that some wells contained elevated concentrations of copper, zinc, and occasionally, arsenic. However, none of the wells studied exceeded the maximum contaminant level for these constituents (VSCC, 2003). It was concluded that contamination from Summitville does not pose a human health threat.

Rocky Mountain Consultants, Inc. (RMC) completed surface and ground water sampling at the Summitville Mine and offsite areas for CDHPE. The objectives of this sampling included monitoring the effects of remediation on downstream water quality, obtaining water quality data, and providing information on metals concentrations from on–site seeps and ground water (RMC, 2000). Several of the seeps sampled had low pH values and both ground water and seep sampling detected high metals concentrations.

Due to the limited amount of ground water quality monitoring data and impact assessment studies in the lower watershed, residents have requested additional testing and monitoring. An extensive water quality monitoring program should continue to monitor acid mine drainage impacts on ground water quality. As the proximal portion of the alluvial fan will typically have higher transmissivities and greater surface water loss rates to ground water, this area should be the focus of a lower watershed study. Specific constituents that should be documented include copper, iron, aluminum, zinc, pH, hardness, and alkalinity. This information can be acquired in conjunction with water level monitoring in the basin.

2.5.5 Ground Water Summary

The Alamosa River watershed has been significantly impacted by human disturbances such as mining, agriculture, and channel straightening. Heavy irrigation use, and the recent drought have caused a decline in the ground water table. Open pit mining and heap leach mineral processing at the Summitville Mine have further impaired ground water quality, which is naturally high in mineral content.

Due to the connection between surface and ground water in the alluvial aquifer, understanding the relationship between the Alamosa River and the underlying aquifer is crucial to determining a remedial action which may raise the ground water table and improve water quality. The limited amount of existing data warrants the development of a study plan, which should include long term monitoring. The purpose of this monitoring plan will be to collect adequate data on ground water levels and ground water quality at various locations along the Alamosa River and the alluvial fan near Capulin. These data may then be used to create a ground water model to determine seepage zones and water loss rates throughout the watershed. While baseline data are limited, the extent of impacts from the Summitville Mine can more readily be determined by collecting additional water quality data in the lower watershed.

2.5.6 Key Ground Water Issues

Based on a review of existing information, the following key issues affecting ground water in the Alamosa River watershed were identified:

- Agricultural land use, irrigation, and drought have caused groundwater levels to decline.
- Naturally high metal content and mining activity in the upper watershed may have negatively impacted groundwater quality.
- Due to the limited amount of existing water quality data regarding groundwater basins affected by the Alamosa River, additional monitoring is necessary to accurately assess existing groundwater conditions.

2.6 Terrace Reservoir

Terrace Reservoir (State Dam ID No. 210102) is located on the Alamosa River about 12 stream miles upstream of Capulin. Terrace Reservoir is owned and operated by the Terrace Irrigation Company (TIC). The principal purpose of the reservoir is to store water for agricultural uses. There are 27 shareholders and 831–7/8 shares of stock. The TIC sets an annual assessment to be paid by the shareholders. On average, 15,339 acre–feet of water is diverted by the TIC through Terrace Main Canal and the Alamosa Creek Canal during any given year (CWCB, 2004).

The reservoir has a storage capacity of about 15,200 acre–feet at normal operating pool (elevation 8,571) and a corresponding footprint of about 300 acres. The reservoir is impounded by a large earth and rockfill dam constructed across a narrow canyon cut down by the river through volcanic rocks. The various phases of the dam construction began in 1903, and construction was completed in 1912.

Elevations in the watershed tributary to Terrace Reservoir vary from about 8,500 feet to about 13,300 feet above mean sea level (msl). The vegetative growth immediately above the reservoir consists largely of piñón trees with an undergrowth of range grass. Between elevations 9,000 to 11,000 feet the vegetation changes to aspen, pine, spruce and fir trees with an undergrowth of range grasses. Above 11,000 feet the growth becomes high altitude grasses, willows, brush, and tundra.

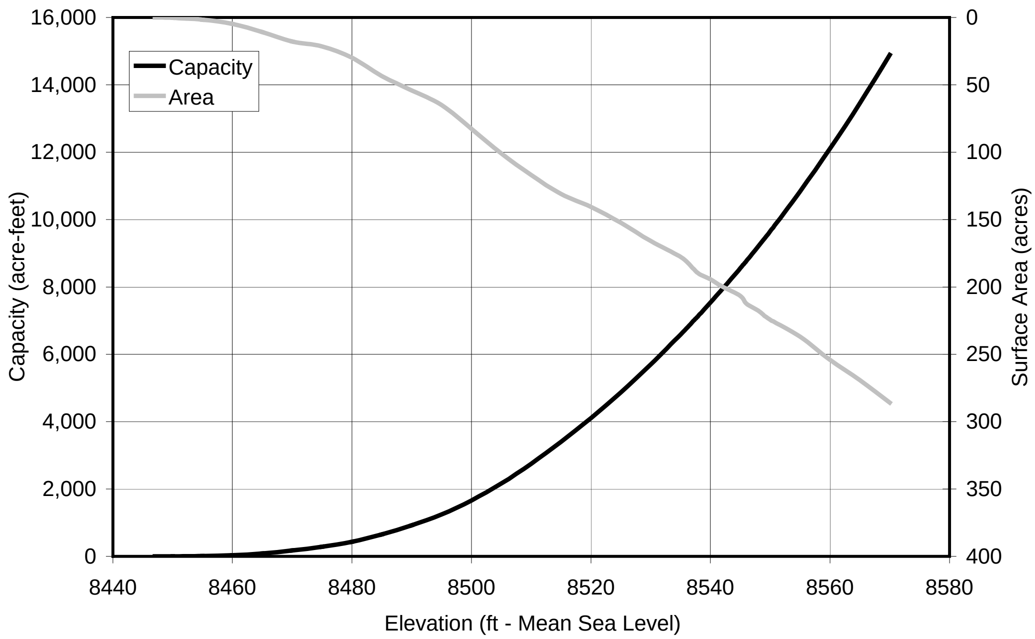
The maximum watercourse length within the basin is about 25 miles and the watershed area above the reservoir is about 116 square miles. The mountains of the basin are volcanic in origin and most of the valleys have undergone alpine glaciation.

2.6.1 Terrace Reservoir Facilities

Terrace Dam

Terrace Dam was constructed using primarily hydraulic fill methods (see Glossary, **Appendix H**). The Colorado State Engineers Office lists the dam height as 165 feet based on the original design drawings. However, an elevation–capacity table for the dam provided by the Terrace Irrigation Company lists the dam crest at elevation 8,583.9, the spillway crest at 8,571 and the inlet elevation of the trash rack at 8,447 giving a hydraulic height of approximately 124 feet. The area–capacity curve of Terrace Reservoir based on the TIC table is shown in **Figure 2–79**.

Figure 2–79. Area–Elevation–Capacity Curve for Terrace Reservoir



The dam has a crest length of about 545 feet with an overall gentle upstream slope varying between 3 horizontal (H) to 1 vertical (V) and 5H to 1V, and a downstream slope of 2H to 1V. The dam is reported to have been the highest hydraulic fill dam in the world when it was completed in 1912. The dam is classified by the State Engineer's Office as a Large, Class 1 structure. **Figure 2–80** shows a plan view of the reservoir location and major structures. **Figure 2–81** shows an infrared aerial photo of the dam, spillway, and control building. Additional figures of the dam and appurtenances are included in the discussion below.

Historically the dam has performed as intended except in the mid 1950's when the embankment experienced surficial slope failures related to a lack of seepage control. At this time the downstream slope of the dam was reported to have been flattened slightly and drains were installed to control seepage. Consultations with the State Engineer's Office (Dennis Miller) revealed that inspections done by the State Engineer's Office report that these drains do not evacuate water from the embankment, indicating that they are likely not functioning as intended.

Figure 2–80. Terrace Reservoir Plan View

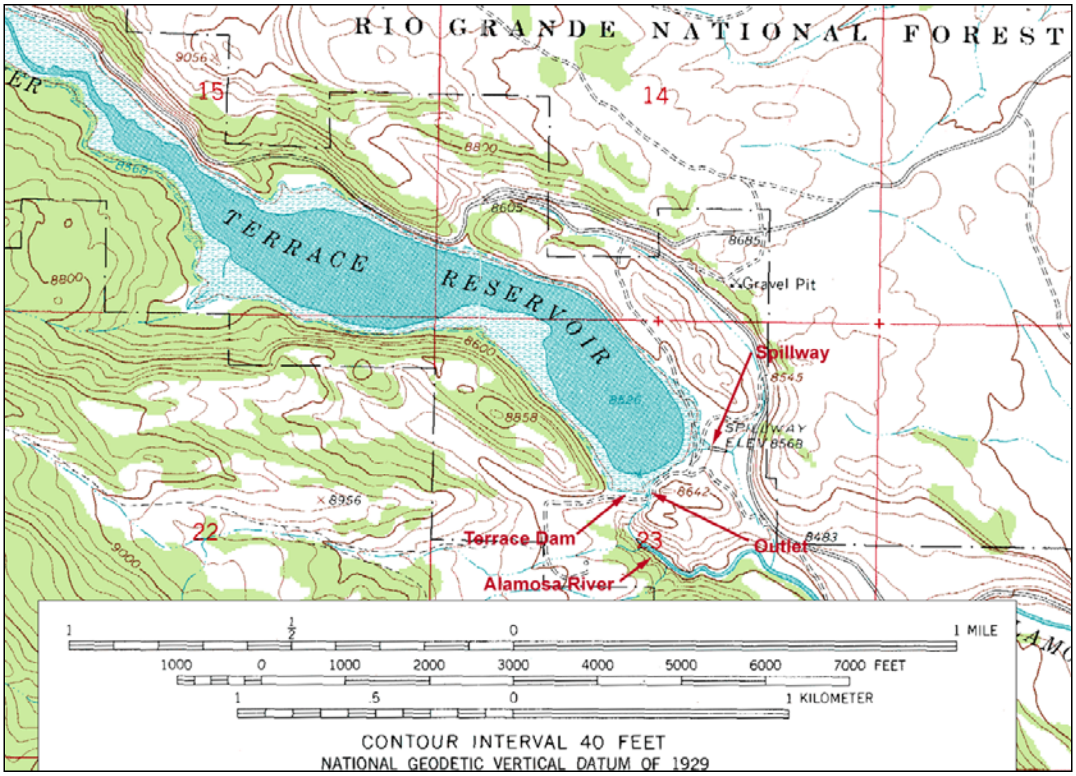
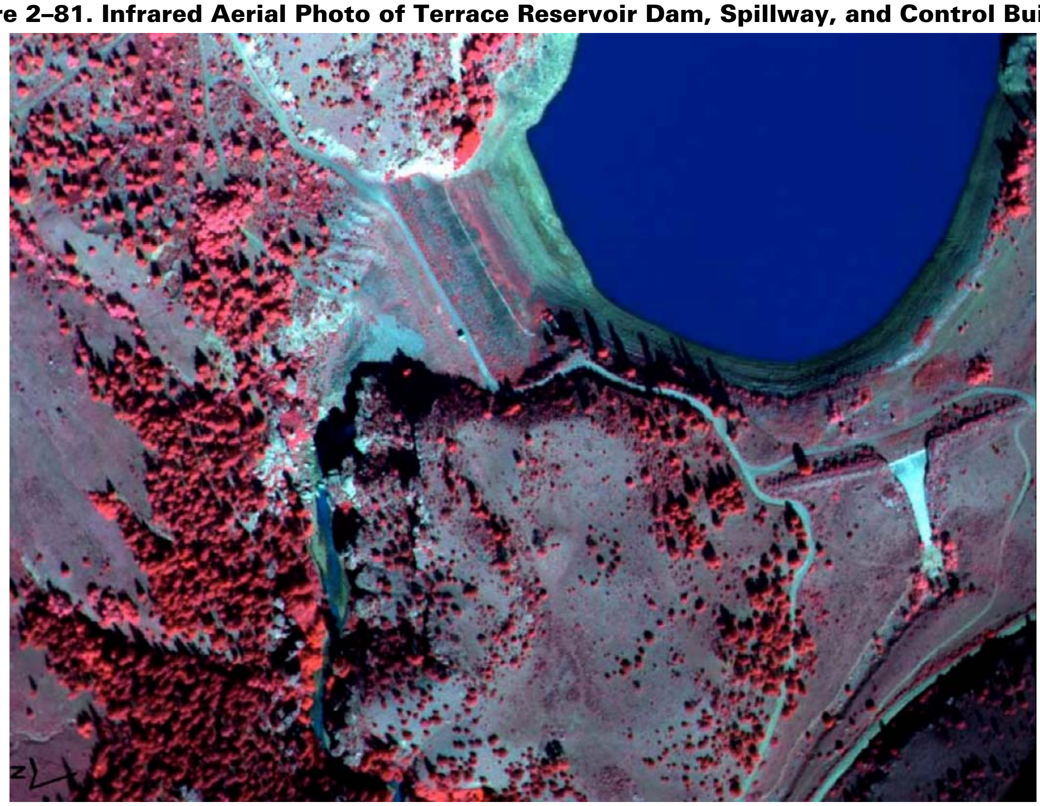


Figure 2–81. Infrared Aerial Photo of Terrace Reservoir Dam, Spillway, and Control Building



The State Engineer's Office (Dennis Miller) also indicated that there is no record of an assessment of the internal stability of the embankment structure. Because the dam is a hydraulic fill structure, possibly subject to internal liquefaction, the structural stability of the reservoir under seismic loading conditions is questionable. The State Engineer's Office indicated they will most likely require that the owner perform this assessment in the future.

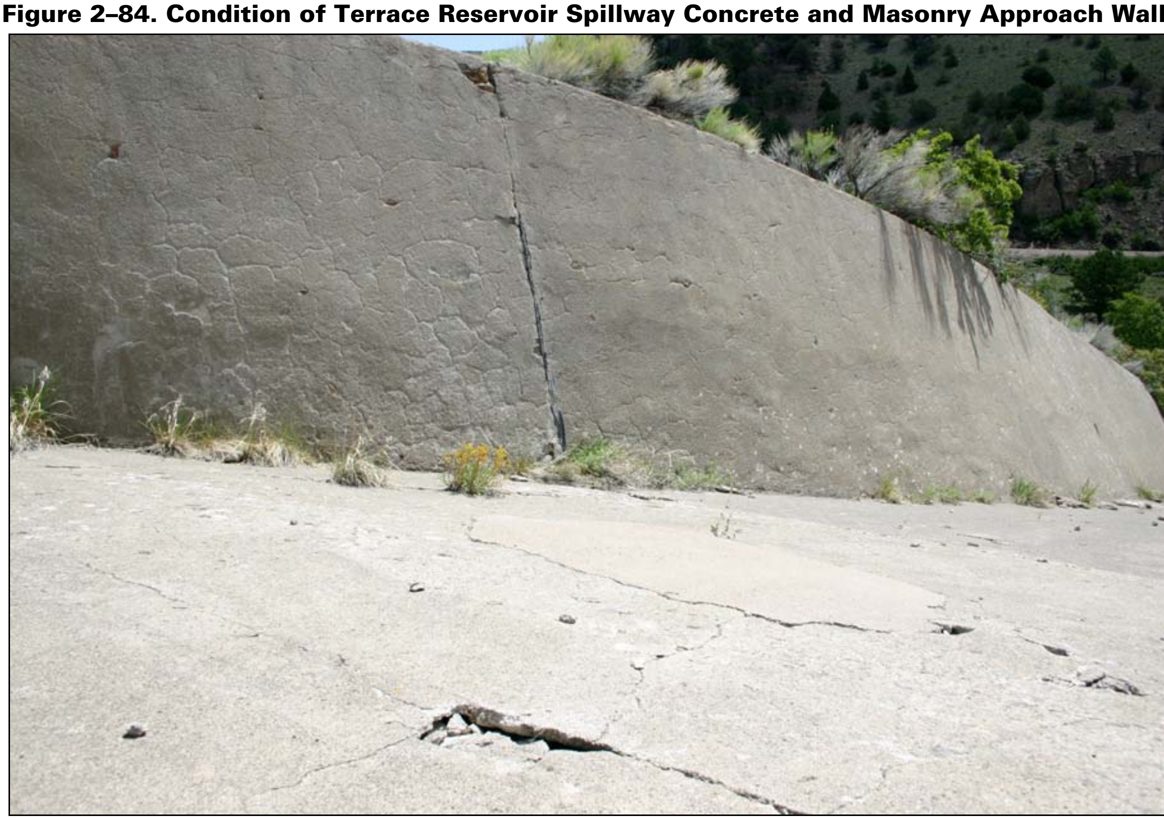
Spillway Structure

The principal spillway is a masonry block chute structure with a concrete ogee crest control 99.5 feet in width, located on a saddle in the east abutment. The spillway is located in glacial end moraine deposits reportedly deposited on top of latite tuft. The condition of the concrete ogee crest is marginally acceptable. The masonry chute structure has been overlaid with concrete. The condition of the overlay concrete is extremely poor with the concrete deteriorating along the length of the chute and in several areas the spillway chute has been undermined. Soundings done on the overlay with a hammer revealed a "drummy sound" when the concrete was struck with the hammer, indicating the overlay is delaminating and/or the concrete is deteriorating. The overall condition of the spillway is poor and it should be replaced or extensively rehabilitated. There is no emergency spillway for the reservoir. **Figure 2–82** and **Figure 2–83** show the reservoir spillway. **Figure 2–84** shows the poor condition of the concrete and masonry.

Figure 2–82. Terrace Reservoir Spillway from Downstream

Figure 2–83. Terrace Reservoir South Abutment and Spillway from Downstream

Figure 2–84. Condition of Terrace Reservoir Spillway Concrete and Masonry Approach Walls



Outlet Structure

The outlet consists of a tunnel bored, using drill and blast techniques, a distance of 917 feet through the solid rock of the east abutment in **Figure 2–85**. It extends from a vertical shaft at the upstream toe of the dam to a discharge portal above the river channel at the downstream toe of the dam. Except at the valve chamber located beneath the dam centerline, the tunnel is unlined rock throughout its length. The rock through which the tunnel was bored has been described as a massive latite–rhyolite flow which forms the walls of the narrow inner gorge of the canyon, being firm, hard and only slightly jointed. The rock exposed in the tunnel walls is very competent and essentially intact. **Figure 2–85** shows the outlet works discharge portal and access adit.

Figure 2–85. Terrace Reservoir Discharge Portal and Access Tunnel

The inlet structure of the outlet is an ungated sloping reinforced concrete structure positioned over the top of the inlet shaft. The inlet shaft is about 15 feet in height and has an approximate square cross section. The inlet structure was constructed in 1959 with the trash racks failing and requiring replacement twice. The trash racks failed in 1971, were redesigned by USBR and replaced. In 2003 the trash racks once again failed during the draining of the reservoir, were redesigned by Davis Engineering Service and subsequently replaced in early 2004. The condition of the inlet structure is relatively good. **Figure 2–86** shows the inlet structure and damaged trash racks that were replaced. **Figure 2–87** shows the inlet structure with the new trash racks.

A pair of 48–inch diameter high–pressure double disc gate valves mounted side by side within the valve chamber control flow through the tunnel (see **Figure 2–88**). Additionally, a single 42–inch diameter Howell–Bunger valve is mounted at the downstream end of the tunnel (see **Figure 2–89**). The right gate valve (facing downstream) discharges directly to the unlined tunnel section downstream of the valve chamber. The left gate valve discharges into a 48–inch diameter steel conduit, which is constructed along the left side of the downstream tunnel section. The 48–inch conduit terminates at the Howell–Bunger valve and is the primary discharge mechanism for the reservoir. The combined discharge of the outlet with all of the gates and the valve open is about 1,160 cfs. The capacity through the left gate and Howell–Bunger valve alone is about 510 cfs.

Figure 2–86. Terrace Reservoir Inlet Structure and Collapsed Trash Racks

Photo courtesy of Joe McCann – District 21 Water Commissioner

Figure 2–87. Terrace Reservoir Inlet Structure with New Beams and Trash Racks

Photo courtesy of Joe McCann – District 21 Water Commissioner

Figure 2–88. Gate Valve Chamber in Tunnel

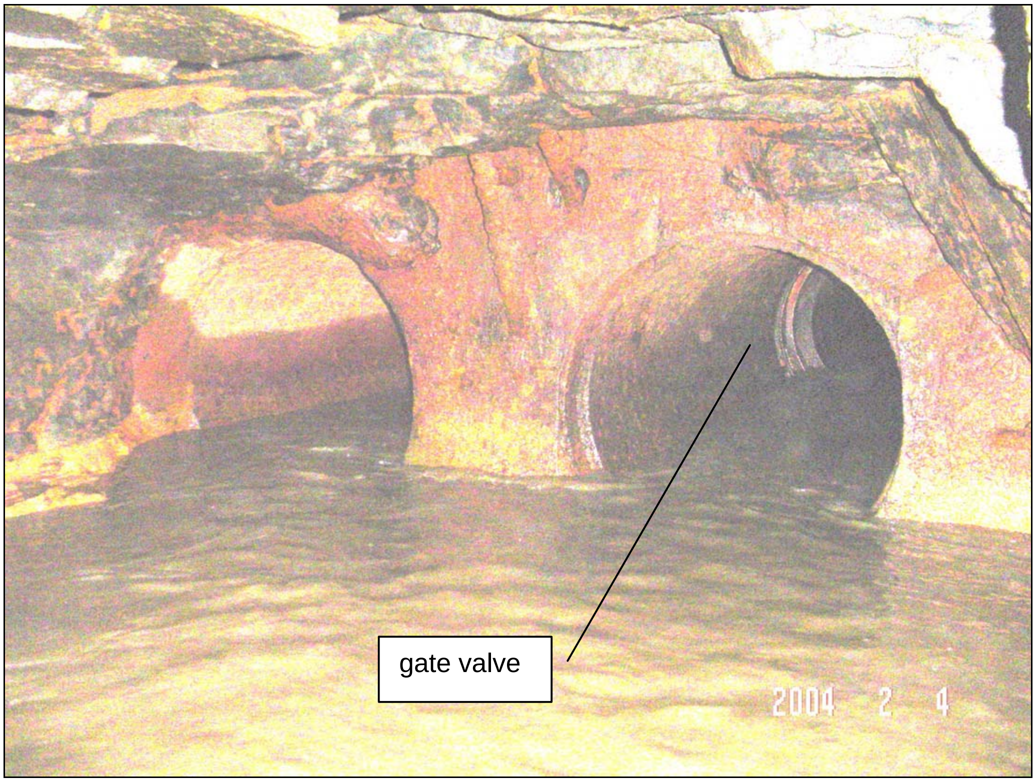


Figure 2–89. Howell–Bunger Valve at Outlet

To regulate flows through the outlet works the gates are operated in a manner to limit vibrations. This is done by closing the west gate and fully opening the east gate, using the Howell–Bunger valve to regulate flow. When the capacity of the east gate has been reached, the west gate is fully opened and the east gate closed. When more water must be released, both gates are fully opened and the Howell–Bunger valve is used to regulate flow through the east gate.

A small diameter vertical shaft, excavated through the dam and the top of the east abutment to the valve chamber, carries the operating stems for the gate valves and allows access to the chamber from the dam crest. Actuation of the gate valves is by hydraulically driven mechanical operators down the shaft. The Howell–Bunger valve is electrically actuated with power provided by an engine generator unit in the gatehouse on the crest of the dam. The electric lines reach the valve through steel conduit down the left groin of the dam.

Considerable corrosion has been observed on the 48–inch diameter steel outlet pipe and on the 42–inch diameter Howell–Bunger valve. The 48–inch steel conduit was designed as having a wall thickness of 0.313 inches. The design did not require a protective paint coating on the conduit because an allowance of 0.063 inches of corrosion was included in the design. Because of the observed corrosion on the valve and conduit and the low pH of the reservoir, the State Engineer, in 1993, requested that the Terrace Irrigation Company hire a metallurgist to evaluate the condition of the steel conduit and the Howell–Bunger valve. To date this study has not been done, or the State Engineer has not seen the results. For the long–term assessment of the outlet it was suggested that this be done.

A detailed review of the maintenance issues of the outlet works system and a description of an inspection of the outlet works was prepared by the Office of the State Engineer (Dennis Miller) and is summarized in a Memorandum of Inspection dated February 5, 2004. This document also summarized the repairs that have been made to the outlet works of Terrace Reservoir.

The mechanical components of the outlet works were state of the practice when the dam was constructed in 1912. Major repairs to the 48–inch double disc gate valves have been required on eight occasions to allow for the continued safe operation of the reservoir. The primary cause of damage to the gate valves has been the combined effect of the sediment load being passed through the gates and the use of the gates for throttling discharge flows. A listing of the year and which valve was repaired is included in **Table 2-23**.

Table 2-23. Summary of Terrace Reservoir Valve Repairs

Year	Valve Repaired
1916	Right Valve Repaired
1928	Both Valves Repaired
1934	Both Valves Repaired
1937	Both Valves Repaired
1971	Both Valves Repaired
1978	West Valve Repaired
1980	Both Valves Repaired
2003	Both Valves Repaired

2.6.2 Spillway Assessment

Due to the high hazard classification of Terrace Dam, the inflow design flood is the Probable Maximum Flood (PMF). The PMF was analyzed in the "Preliminary Engineering Report, Terrace Reservoir Spillway Improvements for Terrace Irrigation Company" (Davis, 1981). Both a general type storm and a thunderstorm were simulated and it was found that the general type storm produced the largest inflow with a PMF peak of 26,898 cfs. The largest historical inflow was 5,200 cfs, recorded on October 11, 1911. Based on the high hazard classification the spillway at Terrace Reservoir is required to pass the PMF or 26,900 cfs.

As noted above, the spillway at Terrace Reservoir is an ogee crested chute spillway with a crest width of 99.5 feet. The spillway is capable of passing about 8,930 cfs when the water level in the reservoir is 1 foot below the crest of the dam (Davis, 1981). Other sources rate the spillway capacity slightly higher, but still only a small portion of the PMF. Because the spillway is unable to pass the design storm, Terrace Reservoir is currently under a filling restriction by the State of Colorado. The operating water level of the reservoir is restricted to a maximum elevation of 8564 or 7 feet below the crest of the existing spillway.

2.6.3 Terrace Reservoir Operation

Terrace Reservoir is operated by Terrace Irrigation Company to supply agricultural water for its shareholders. Water rights and historical reservoir storage levels are discussed in **Section 2.3.3**. The reservoir gates are typically closed during the winter months, once calls on the river have ceased, to store all inflow. During the irrigation season the reservoir continues to store water when in priority, and outflow is regulated to meet the demands of Terrace Irrigation Company shareholders as well as other water rights holders on the lower Alamosa River. Under normal conditions the reservoir can be operated between the minimum conservation pool level of 1,500 ac–ft and the maximum restricted fill level of 13,000 ac–ft.

Sediment loads from the upstream watershed are high due to the natural geology and surface mining activity. This has led to a substantial accumulation of sediment in the Terrace Reservoir pool. There are no current estimates of the volume of sediment captured by the reservoir, or the amount of storage that could be recovered if the existing sediment were removed.

As described previously, the reservoir has been drained several times to accommodate maintenance of the outlet structure. On at least two occasions – 1971 and 2003 – draining the reservoir resulted in significant amounts of sediment being flushed out of the pool and deposited in the downstream channel. In both cases the slug of sediment washed out of the reservoir had significant adverse downstream impacts by reducing channel capacity, impacting aquatic habitat, severely affecting irrigation water quality, and accumulating on agricultural fields in the lower Alamosa River watershed.

2.6.4 Terrace Reservoir Water Quality

Water Quality

Terrace Reservoir is an oligotrophic lake, meaning that the lake is low in nutrients that can lead to algae growth. Thermal stratification, where layers of water of different temperature prevent vertical mixing, occurs in the reservoir from mid–May through August. Prior to stratification, inflow and flow–through patterns vary depending on density differences from temperature and dissolved solids concentrations. In a study by Stogner et al. (1997), cold inflowing water usually underflowed into the hypolimnion, bottom water layer, and directly to the reservoir to the outlet during stratification. Hydraulic residence times in the hypolimnion were on the order of three to five days which was much shorter than in the epilimnion, top water layer.

Prior to open pit mining at Summitville, water quality in Terrace Reservoir was sufficient to maintain fish populations of brook trout, Rio Grande cutthroat, and rainbow trout. In the 1980's the Colorado Division of Wildlife maintained a rainbow trout fishery in Terrace Reservoir.

There is relatively little chemical water quality data for Terrace Reservoir prior to SCMCI operations at Summitville. A water quality sample taken by the US Forest Service in the middle of Terrace Reservoir on July 1, 1968 (from UAA database – see **Section 2.4.4**) had a water pH of 7.8. Samples were taken in Terrace Reservoir by the US Geological Survey in August 1974. Water pH ranged between 7.0 and 8.0. The average dissolved metal concentrations from samples taken from a 1.6 foot and 54 foot depth were 6.5 μg/l for copper, 125 μg/l for iron, 410 μg/l for manganese, and 10 μg/l for zinc (from Stogner et al. 1997). Although the number of samples is too small for statistical confidence, these data suggest that the pH in Terrace Reservoir prior to SCMCI may have often been neutral or even alkaline and that the concentrations of dissolved metals were within current water quality standards.

Table 2-24 presents a summary for water quality data collected in the years following SCMCI operations at Summitville. Unfortunately, water quality samples were not collected from the reservoir during open pit mining operations at Summitville. However, water quality samples collected in 1994 and 1995 still illustrate the impacts of SCMCI operations. Water quality samples collected in Terrace Reservoir between 1998 and 2001 highlight the effects of remediation activities at Summitville, while the three samples collected in May 2003 were influenced by low water levels and increased sediment resuspension prior to the draining of the reservoir. The median hardness value was calculated for each time period in order to approximate the chronic water quality standard (see **Section 2.4.4**). The water quality standard can be compared to the 15^{th} and 85^{th} percentile values. Exceedence of water quality standards is indicated in the table with bold text.

Fish populations in Terrace Reservoir were killed by an untreated release from the Summitville site in 1990. Significant water quality impacts due to SCMCI activities can still be observed in the 1994 and 1995 data. Water pH was below water quality standards, and the 15^{th} percentile value is below the chronic toxicological reference value of 5.6 for rainbow trout (see **Section 2.4.4**). Concentrations of copper, zinc, iron, and aluminum also exceeded water quality standards.

A significant improvement in water quality can be noted in the 1998 to 2001 water quality data as a result of remediation activities at Summitville. The median pH in the reservoir was neutral at 7.0, and levels of dissolved metals were significantly reduced. Only concentrations of total iron were in exceedence of water quality standards.

Table 2-24. Water Quality in Terrace Reservoir Following SCMCI Activities

Parameter	Form		1994–1995	1998–2001	2003
pH		median	6.4	7.0	6.3
		15th percentile	5.5	6.7	6.2
		chronic standard	6.5	6.5	6.5
Copper	Dissolved	median	785	4	3
	Total	median	680	10	60
	Dissolved	85th percentile	860	10	3
	Dissolved	chronic standard	7	11	6
Zinc	Dissolved	median	245	30	20
	Total	median	230	40	50
	Dissolved	85th percentile	310	70	60
	Dissolved	chronic standard	91	139	82
Iron	Dissolved	median	1,415	20	600
	Total	median	1,710	540	8,550
	Total	85th percentile	3,170	1,225	11,300
	Total	chronic standard	1,000	1,000	1000
Aluminum	Dissolved	median	285	0	0
	Total	median	450	130	5,750
	Dissolved	85th percentile	530	9	30
	Dissolved	chronic standard	87	87	87
Manganese	Dissolved	median	615	340	330
	Total	median	570	310	370
	Dissolved	85th percentile	910	490	340
	Dissolved	chronic standard	1,489	1,760	1,426

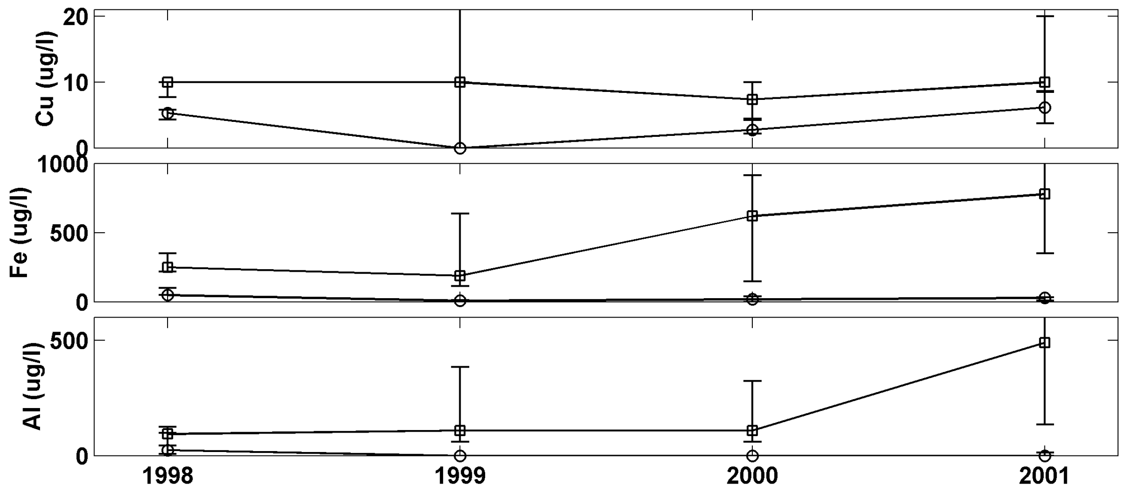
Notes: All metal concentrations in μg/l, bold text indicates exceedence of water quality standard
For 2003 data, 85th percentile value taken as the maximum of the 3 samples
Many dissolved and total concentrations determined from different samples

Stogner et al. (1997) intensively studied the physical and chemical characteristics of Terrace Reservoir between May 1994 and May 1995. During the study, the reservoir remained well oxygenated and dissolved oxygen varied little with depth, indicating that few biological processes were occurring. Water pH ranged from near 7.0 during snowmelt to almost 4.0 during mid–summer. On similar dates, the water pH generally decreased in the downstream direction. This acidification could have been due to the formation of hydroxides in the reservoir; although Stogner et al. suggested that daily fluctuations in inflow pH could have also created this pattern in the data set. During stratification, pH generally became lower with depth. On June 15, 1994, water pH near the center of the lake was about 6.6 at the surface and 5.3 at the bottom. On July 11, the pH was 5.1 near the surface and 4.55 at the bottom. As the outlet of Terrace Reservoir draws from the hypolimnion during stratification, the lowest pH water was being passed downstream to irrigators. The lower pH with depth could have been related to the pH of inflow or caused by the formation of iron hydroxides in the reservoir. Inflow pH was as low as 3.6, and Stogner et al. felt the hypolimnetic pH was related mostly to the pH of inflow.

During the Stogner et al. study, metals remained primarily in the dissolved form. During stratification, concentrations of iron in the epilimnion decreased markedly in the downstream direction due to settling of colloidal iron hydroxides. The hypolimnion was well mixed, and concentrations were relatively uniform longitudinally. However, metal concentrations increased with depth. During June 1994, copper concentrations increased from about 150 μg/l near the surface to about 750 μg/l near the reservoir bottom. In July, copper concentrations ranged from about 850 μg/l near the surface to almost 1100 μg/l near the bottom. Therefore, the highest concentrations of metals were also passed downstream during the irrigation season.

During the 1994 to 1995 time period, dissolved and total metals concentrations were relatively similar. During the 1998 to 2001 time period, total concentrations of copper, iron, and aluminum were higher than dissolved concentrations. Proportions of total and dissolved zinc and manganese were relatively similar. **Figure 2–90** shows median total and dissolved concentrations of copper, iron, and aluminum. Total copper concentrations remained about 5 μg/l higher than dissolved concentrations. Concentrations of dissolved iron and aluminum were near zero while total concentrations rose during the time period. This would seem to indicate that a large portion of iron and aluminum were in colloidal or particulate form during the time period and may have settled in the reservoir. Some copper may have been precipitating and settling in the reservoir.

Figure 2–90. Total versus Dissolved Metal Concentrations in Terrace Reservoir, 1998 to 2001



Note: Square = median total concentration, circle = median dissolved concentration

Error bars indicate 25th and 75th percentile concentrations

Available water quality data downstream of Terrace Reservoir was examined in depth in **Section 2.4**. The data also indicated that water quality from Terrace Reservoir was severely impacted following SCMCI activities, but progressively improved following remediation activities at Summitville. Between 1998 and 2003 below Terrace Reservoir, the 15th percentile pH value was 6.17 and the 85th percentile concentrations for copper and iron were 11.0 μg/l and 2060 μg/l, respectively. These values are still in exceedence of the CDPHE chronic water quality standards and are worse than the water quality conditions observed in Terrace Reservoir during the same time period. This may also confirm that as the reservoir stratifies during summer months, inflowing water quickly passes through the hypolimnion to the outlet and has less time for particulates to settle and water quality to improve than in the epilimnion of the reservoir.

Water quality conditions declined considerably during 2003. The statistics in **Table 2-24** were calculated from three samples taken on May 22, 2003. At this time, reservoir levels were relatively low and the Alamosa River was degrading through the sediments at the head of the reservoir. However, water quality in the reservoir probably became significantly worse during the fall and winter months of 2003 and 2004. During May 2003, pH was in exceedence of the water quality standard. Concentrations of total aluminum and iron increased significantly, and total copper increased somewhat, as sediments were probably resuspended and mixed into the water column.

During the draining of Terrace Reservoir in 2003, students from the Alamosa Open High School confirmed that the resuspension of Terrace Reservoir sediments significantly degrades water quality. The Alamosa Open High School has been sampling water quality as part of the River Watch program and sampled water upstream and downstream of Terrace Reservoir in fall of 2003 (ARWRF 2003). On September 16, 2003, water pH above Terrace Reservoir was 6.2 while pH below Terrace Reservoir at the Gomez Bridge was 5.0. At the same time, water turbidity was observed to increase from about 12 Nephelometric Turbidity Units (NTU) to 110 NTU. On October 9, 2003, water pH was 6.0 above Terrace Reservoir and 4.2 below. The bottom sediments that were being eroded and resuspended into the water column significantly lowered the pH.

Untreated releases from the Summitville site pose a continued risk to water quality conditions in Terrace Reservoir. Copper concentrations were measured in the reservoir before and after a release of untreated water from the SDI at the Summitville site in May of 2001 (RMC 2001). Before the release on April 14, dissolved copper concentrations averaged 6.5 μg/l (the reservoir was well mixed). On May 26 following the SDI release, copper concentrations varied from about 11 μg/l at the surface of the reservoir to 15 μg/l at a depth of 65 feet. A notable change in pH was not observed.

A caged fish study was conducted in October and November of 2000, and all 150 rainbow trout survived during the study. 7003 rainbow trout were released on July 2001, and appeared to have good survival rates. The fish were killed during draining of the reservoir in 2003 (Joe McCann, oral commun. 2004). The survival of fish between July 2001 and 2003 demonstrates the success of remediation efforts at Summitville. However, no untreated releases occurred from the Summitville site during this time period. It is not known if fish populations in Terrace Reservoir will be able to survive large untreated releases, and the probability of untreated releases from the Summitville site remains high (see **Section 2.4.3**).

Sediments and Metals Deposition

Terrace Reservoir has acted as a sink for water quality contaminants. At least 10 to 20 feet of sediment has accumulated in the bottom of Terrace Reservoir since its construction. Some portion of heavy metals may have been adsorbed to the sediments, precipitated, or settled in colloidal or particulate form.

Table 2-25 shows estimates of annual loads of metals that were transported into and out of Terrace Reservoir and deposited in Terrace Reservoir from three time periods. Ferguson and Edelman (1996) assessed the transport of metals into and out of Terrace Reservoir and quantified the deposition of metals in the reservoir from April 1994 through March 1995. Ortiz et al. 2002 studied metal loads in the Alamosa River above Terrace Reservoir and below Terrace Reservoir from mid–1995 through 1997. Loads deposited in Terrace Reservoir in 1997 were calculated from the load estimates presented in **Table 2-19**. Annual current metal loads in Alamosa River reaches were estimated in **Section 2.4.9** (**Table 2-20**) using median concentrations from the 1998 to 2003 time period and the average streamflow for these reaches. Average current loads deposited in Terrace Reservoir are estimated as the difference in the reach loads upstream and downstream of Terrace Reservoir.

Table 2-25. Annual Metal Loads in Terrace Reservoir; 1994–1995, 1997, and 1998–2003

	Dissolved Copper (ton/yr)	Total Copper (ton/yr)	Dissolved Zinc (ton/yr)	Total Zinc (ton/yr)	Dissolved Iron (ton/yr)	Total Iron (ton/yr)	Dissolved Aluminium (ton/yr)	Total Aluminium (ton/yr)
Load In (94–95)	44	61	19	20	172	790	25	363
Load Out (94–95)	37	39	18	18	78	194	19	69
Load Deposited (94–95)		22		2.2		597		295
Percent Deposited (94–95)		36%		11%		76%		81%
Load In (1997)	4	23	12	15	30	1140	5.0	670
Load Out (1997)	2.9	6.2	9.0	9.5	6.0	148	4.0	84
Load Deposited (1997)		17		5.5		992		586
Percent Deposited (1997)		73%		37%		87%		87%
Load In (98–03)	0.8	8.7	7.6	9.5	10.9	362.2	1.0	216.3
Load Out (98–03)	0.3	1.7	3.3	4.4	4.5	90.7	0.0	20.8
Load Deposited (98–03)		7.0		5.1		271		196
Percent Deposited (98–03)		81%		54%		75%		90%

Notes: 1994–1995: April to March loads estimated by Ferguson and Edelman (1996)
1997: Annual loads estimated using data from Ortiz et al. 2002 as presented in **Table 2-19**
1998–2003: Average annual load as presented in **Table 2-20** estimated using median metal concentration from upstream and downstream reaches and average streamflow

Loads of iron and aluminum were higher in 1997 than 1994/95 but have decreased significantly in the 1998 to 2003 time period due to remediation activities at the Summitville site. The percentage of iron deposited in Terrace Reservoir has remained relatively constant at about 75% to 87% of the incoming load. The percentage of deposited aluminum has increased slightly from 81% to 90% and appears related to an increasing portion of aluminum in particulate rather than dissolved form. The load of copper deposited in Terrace Reservoir has steadily decreased. However, the percentage of copper deposited in Terrace has increased significantly from 36% to 81% of the total incoming load. The load of zinc deposited in the reservoir increased between 1994 and 1997 and continued to increase between 1997 and 2004. In this case, the increase in percentage deposited from 11% to 54% was larger than the reduction in incoming loads over the time period. The increased percentage of copper and zinc loads deposited in the reservoir also appears directly related to the greater portion of metals being in particulate or colloidal form rather than dissolved form. The shift to more particulate forms is probably related to increasing pH in the Alamosa River and Terrace Reservoir following remediation activities at Summitville.

Bottom sediment and shorelines deposits were sampled from Terrace Reservoir in September 2000 as part of the 2000 Data Gap Study (RMC, 2000b). Sediment samples were also taken from Terrace Reservoir after much of the reservoir had been drained in September 2003 (Tetra Tech RMC, 2004). **Figure 2–91** shows the location of sediment samples. Sample locations can generally be grouped into the shoreline area, riverine zone, transition zone, and lacustrine zone, and dam face area, and samples taken within these areas generally had similar characteristics. The particle size distribution of year 2000 samples was examined. In reservoir bottom areas not near the shoreline, greater than 99 percent of the sediment was in the clay/silt size range indicating they came from settled suspended sediments rather than riverine bedload. **Table 2-26** presents the metal concentrations of the sediment samples (in mg metal per kg soil), the paste pH of the sediment samples when water was added, and the extracted metals (in μg/l) that would be potentially soluble, averaged by year and zone.

Figure 2–91. Location of Terrace Reservoir Sediment Samples

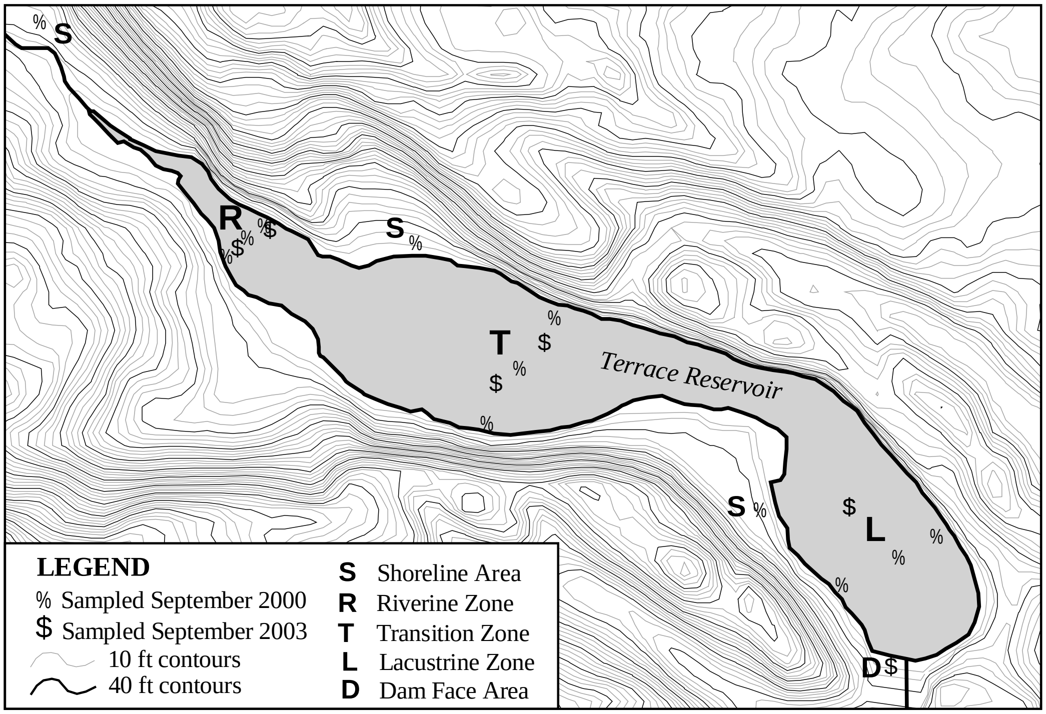


Table 2-26. Chemical Composition of Terrace Reservoir Sediment Samples

Parameter	Year	Shoreline	Riverine	Transition	Lacustrine	Dam Face
Aluminum (mg/kg)	2000	11,500	17,867	28900	27,833	
	2003		12,400	23050	22,700	24,300
Copper (mg/kg)	2000	309	564	1473	1,200	
	2003		244	879	920	1,630
Iron (mg/kg)	2000	33,933	44,433	87333	86,667	
	2003		39,400	73800	69,400	200,000
Zinc (mg/kg)	2000	179	167	243	372	
	2003		118	273	229	335
Manganese (mg/kg)	2000	778	380	917	1,636	
	2003		366	1,315	1,235	1,830
Cadmium (mg/kg)	2000	3.7	3.9	7.3	6.7	
	2003		1.0	1.0	1.0	3.0
Paste pH	*	5.2	5.4	5.6	5.7	6.0
Soluble Copper (µg/l)[1]	*	17	<10	35	47	<10
Soluble Iron (µg/l)[1]	*	80	170	55	105	100
Soluble Cadmium (µg/l)[1]	*	0.3	<5	<5	<5	
Acid Volatile Sulfide(umol/g)	2000		0.016	<0.004	<0.004	

Note: * Shoreline samples collected 2000, other area samples collected 2003
(1) Potentially soluble metals using Synthetic Precipitation Leachate Procedure (EPA Method 1312)

Sediment in Terrace Reservoir contains a very high concentration of metals. Aluminum and iron constitute about 10% of the sediment by mass in the transition and lacustrine zones. Metal concentrations increased between the riverine zone and the deeper transition and lacustrine zones. Concentrations of iron and aluminum were highest in the transition zone in both year 2000 and 2003 samples. In year 2000, copper concentrations were also higher in the transition zone, while concentrations of zinc, manganese, and cadmium were higher in the lacustrine zone. This trend reversed in year 2003. Metal concentrations in the shoreline areas were lower than in the reservoir bottom areas. However, sediments collected on the dam face in 2003 generally had higher metal concentrations than other locations. Metal concentrations generally decreased between year 2000 and 2003. This may be a result of improved inflowing water quality, and metal concentrations may be decreasing in the top layers of sediments that have been deposited since the initiation of remediation activities at the Summitville site. Paste pH for year 2000 shoreline sediments and year 2003 bottom sediments ranged between 5.2 and 6.0. Therefore, sediments have the potential to lower water pH in Terrace Reservoir, especially if resuspended.

Year 2000 shoreline sediments and year 2003 bottom sediments were also tested for potentially soluble metals using the Synthetic Precipitation Leachate Procedure (SPLP) EPA Method 1312. In SPLP, the sediment is saturated with an acidic pH 5.0 solution, and concentrations of metals in the solution leachate are measured. The pH 5.0 solution was designed to represent potential exposure to acid rain in the western U.S. However, sediments in Terrace Reservoir could potentially be exposed to pH 5.0 inflow. Copper concentrations in leachate exceeded water quality standards in year 2000 shoreline sediments and year 2003 transition and lacustrine zone sediments. Iron and cadmium leachate concentrations remained below water quality standards or below detection limits although the reported detection limits for cadmium for year 2003 were above water quality standards. Although the concentrations were low they could still add to metal loading in the reservoir.

Bottom sediments taken in 2000 were evaluated using an acid volatile sulfides and simultaneous extracted metals (SEM/AVS) analysis. Sulfides are thought to bind metals in sediments and prevent them from becoming bioavailable. It is thought that sediments will not generate metals if the number of molecules of acid volatile sulfides are greater than the number of molecules of simultaneous extracted metals (EPA 1999). Very low amounts of sulfides were detected, and an analysis of the average simultaneous extracted metals presented in RMC (2000b) indicates that several orders of magnitude more molecules of copper were extracted than volatile sulfides. Therefore, sulfides are not binding the metals in Terrace Reservoir sediments, as expected in a highly oxidized, aerobic environment like Terrace Reservoir. Iron compounds may have the potential to bind some trace metals.

Therefore, Terrace Reservoir sediments have the potential to lower water pH and produce copper concentrations that may exceed water quality standards when submerged. However, the degree to which this may be happening is not known. The high clay content of the sediments should limit exchange between sediment pore waters and the water column and upper layers should act to "seal" exposure to lower layers. Overall, water quality generally seems to improve below Terrace Reservoir. However, this does not always appear to be the case during periods of high flow out of Terrace Reservoir and was definitely not the case in 2003 while the reservoir was being drained. It would appear that water quality is definitely degraded if sediments are resuspended. Resuspension of sediments would greatly increase particulate metals and tend to lower pH. The lower pH may then tend to transform particulate copper in the water column back into dissolved copper.

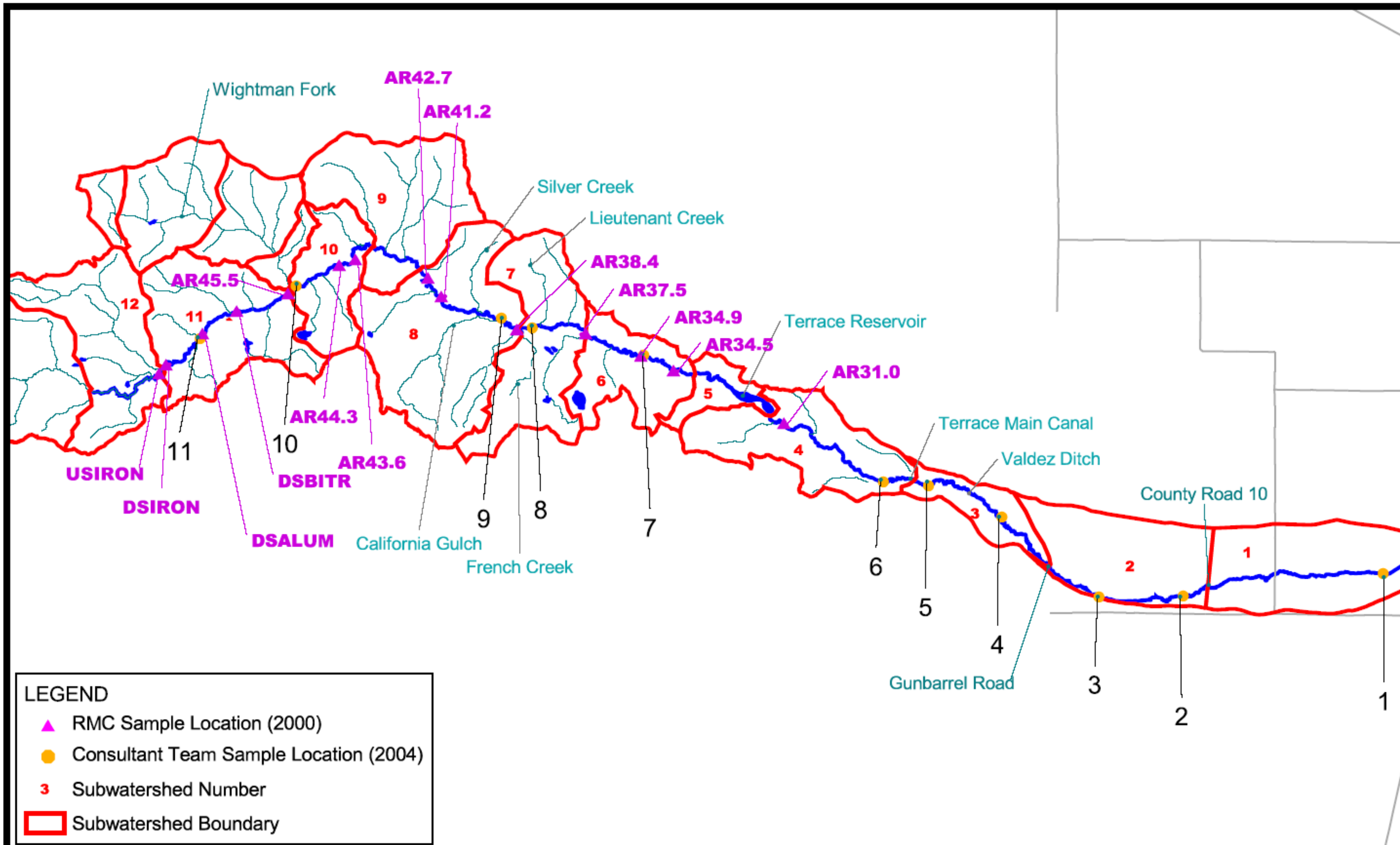
2.6.5 Summary of Terrace Reservoir Issues

This following is a summary of issues with the current Terrace Reservoir facilities and operations that should be addressed by the Master Plan:

- The spillway is insufficient to pass the Probable Maximum Flood design inflow. The State Engineer has imposed a filling restriction that limits the water level in the reservoir.
- The dam was never constructed to the originally planned height. The dam could be raised, but a stability and liquefaction analysis would be required to assure the safety of the structure.
- The outlet structure has been a chronic source of problems and has required dewatering of the reservoir and subsequent flushing of sediment downstream.
- When the reservoir is emptied in the future, there must be a more effective method of preventing large quantities of sediment from being washed downstream.
- Deposition of metals and sediments in the reservoir has tended to improve downstream water quality. However, hypolimnetic water with the lowest pH and highest metal loads is often passed downstream to irrigators because the reservoir outlet is at the bottom.
- Resuspension of bottom sediments appears to lower pH and increase metals concentrations.

2.7 Sediment

To analyze the sediment conditions in the Alamosa River, the watershed was divided into the following four sections: 1) The upper watershed above Terrace Reservoir, 2) Terrace Reservoir, 3) Terrace Reservoir to Gunbarrel Road, and 4) Gunbarrel Road to Highway 285. The upper watershed is a source of high sediment loading to the Alamosa River. When the river slope flattens, the stream does not have the power to keep that much sediment suspended. Terrace Reservoir captures the majority of sediment contributed by the upper watershed because the quiescent conditions allow sediment to settle to the bottom. Downstream of Terrace Reservoir, the river again picks up a new sediment load. The sediment transport capacity of the Alamosa River downstream of Terrace Reservoir is greatly affected by irrigation diversions, channel straightening, and the natural characteristics of the alluvial fan. In July 2004 material size information was collected to better understand and characterize the Alamosa River channel. Wolman Pebble Counts at the sample locations were used to characterize the material armoring the channel bed and bars. The results of the Wolman Pebble Counts help define the size of material transported by the Alamosa River. Locations where Wolman Pebble Counts were completed in 2004 and Rocky Mountain Consultants took sediment samples in 2000 are presented in **Figure 2–92**.



2 0 2 4 Miles

1:240000

Alamosa River Watershed
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Figure 2-92.
Sediment Sample Locations

2.7.1 Upper Watershed above Terrace Reservoir

An understanding of regional geology is crucial in order to determine the quantity and type of sediment entering the Alamosa River. The headwaters of the Alamosa River lie in the San Juan Mountains, which are part of an extensive Oligocene volcanic field (Steven and Epis, 1968). The following three major periods of volcanism have been delimited:

1) 35 to 30 million years ago (Ma) intermediate lavas erupted from widespread stratovolcanoes resulting in deposition of the Conejos Formation (intermediate refers the rock classification based on silica content and is a reflection of the chemistry of the rock),
2) 30 to 26.5 Ma voluminous silicic ash–flow tuffs and intermediate lava flows were accompanied by regional collapse to form large calderas, and
3) 26.5 to 4 Ma late eruption of bimodal basalt and rhyolite (Lipman et al., 1970; Steven, 1975).

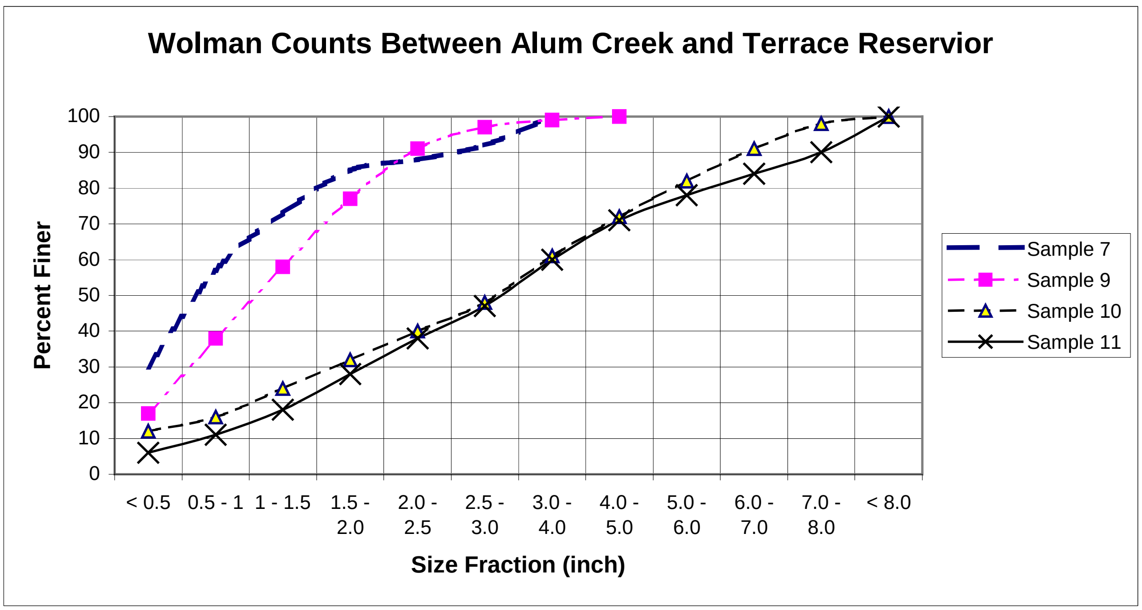
The upper watershed of the Alamosa River was a highly active volcanic area. The youngest Hinsdale Formation flows make up the Los Mogotes shield volcano, which comprises the upper Alamosa River watershed. This sequence of 12 olivine–bearing basaltic–andesite flows erupted approximately 5 Ma and continued over a period of a few hundred thousand years (Lipman and Mehnert, 1975). Due to the extensive volcanic activity and later stages of hydrothermal alteration, a large volume of highly erodible material became readily available for transport by the Alamosa River and its tributaries (see **Section 2.4**).

Numerous landslides and debris flows, typical of a steep and geologically active area, have also contributed to the Alamosa River sediment loading. Alum Creek and other tributaries in the upper watershed are capable of depositing large amounts of pyritic soils in the river during debris flows triggered by intense thunderstorms (CGS, 1995). **Figure 2–93** shows the high sediment load deposited by a tributary channel. The large amount of material present during the July 2004 site visit at the Iron, Alum, Bitter, and Burnt Creek confluences indicates that these tributaries contribute significant amounts of sediment.

Sediment in the upper watershed is comprised of large cobbles and boulders. Material size analysis shows that the upper watershed median bar material size ranges from 1 to 3 inches, with a maximum size ranging from 3 to 36 inches. The graphical mean ranges from 1.2 to 3.9 inches. Smaller sediment sizes were measured in the reaches immediately upstream and downstream of the confined reach, Reach 7 (sample locations 7 and 9). Refer to **Figure 2–94** for sediment distribution curves for the upper watershed. Generally it is the smaller sand size fragments and finer sediments that leach and contribute metals to surface waters, and not the larger fragments.

Figure 2–93. Photo of Alum Creek Channel Showing High Sediment Load

Figure 2–94. Upper Watershed Sediment Distribution Curves



See sample locations in Figure 2–92

In addition to the highly erodible material present across much of the upper Alamosa River watershed, there are also numerous abandoned mine openings and spoil piles, which may contribute to the sediment loading. CGS inventoried 219 mine openings and 130 mine dumps in the Alamosa River Basin in 1993 and 1994. The majority of these mines are in the upper watershed and have tailings piles containing less than 1,000 cubic yards of material. The Pass Me By Mine is located in the Iron Creek drainage and has the second largest spoils pile (10,000 cy), exceeded only by the spoil pile at the Summitville Mine. Following a mine inventory in 1993, the CGS concluded that "the mine dumps are generally stable and add little to the sediment load, especially when compared to the erosion that affects outcrops of weathered, altered bedrock." (CGS, 1995). **Figure 2–95** shows trees growing though the Pass–Me–By spoils pile indicating the pile is relatively stable.

Figure 2–95. Photo of the Pass Me By Mine Spoils Pile

2.7.1 Terrace Reservoir

Terrace Reservoir captures nearly all of the finer sediment load transported from the upper Alamosa River watershed including sand, silt, and heavy metals. This significantly alters the sediment loading downstream. The majority of cobbles and gravel drop out before reaching the reservoir. The Alamosa River downstream of the reservoir then picks up a new sediment load from the channel bed and banks in an attempt to regain its sediment balance.

Drainage of Terrace Reservoir has historically caused sediment problems in the lower watershed. In fall of 1970, Terrace Reservoir was drained, and a cofferdam was built within the reservoir in order to repair the leaking gates. In September, heavy rains in the upper watershed produced a flow of 1,190 cfs which breached the cofferdam. Sediments in the reservoir were washed through the open gates into the lower Alamosa River. The sediments filled the Alamosa River channel to Highway 285. In order to prevent winter flooding, the U.S. Army Corps of Engineers issued Conejos County a grant to clean the silt and debris from the channel. Contractors cut a straight channel through about 4.5 miles of the historically meandering river. While alleviating immediate flooding concerns at the time, this channel straightening has contributed to many of the river function problems currently faced on the lower Alamosa River.

Terrace Reservoir was also drained in the winter of 2003/2004. During the draining, the river cut a deep channel through the fine sediments that have collected in the reservoir (see **Figure 2–9** in **Section 2.2**) and carried the sediments downstream into the lower Alamosa River. Approximately three feet of sediment were deposited in upper reaches of the lower Alamosa River, approximately two feet were deposited upstream of Gunbarrel Road, and approximately one foot was deposited downstream of Capulin. **Figure 2–96** shows a photo of the sediment deposition near the USGS gage downstream of Terrace Reservoir. There were no sediment samples taken here.

Figure 2–96. Photo of Terrace Sediments Deposited Near USGS Gage in 2003/2004

2.7.2 Terrace Reservoir to Gunbarrel Road

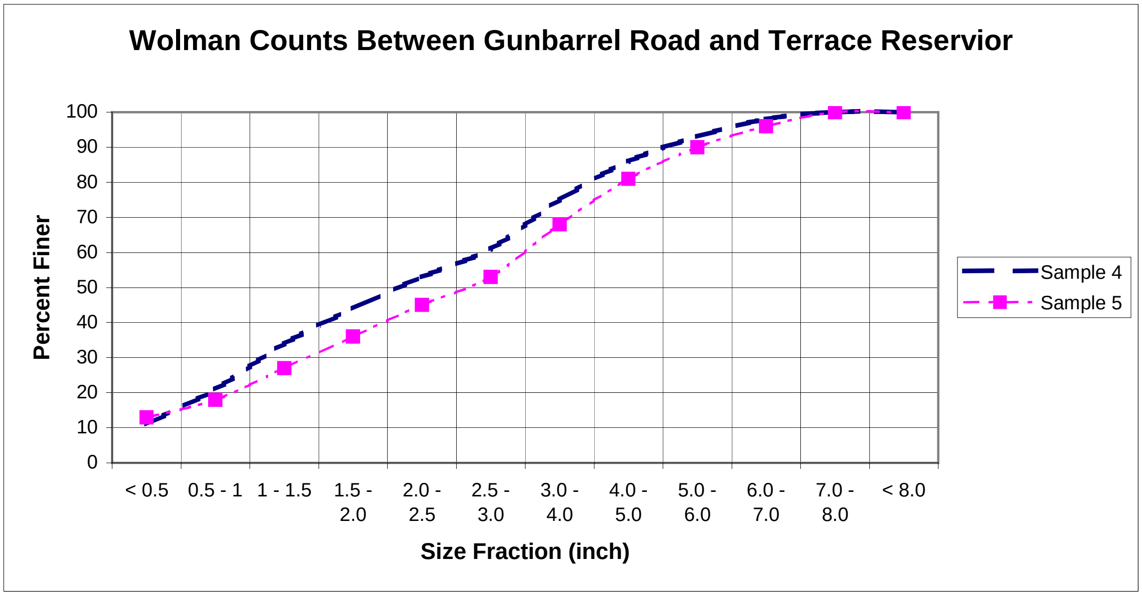
Historically, the river between Terrace Reservoir and Gunbarrel Road had a high sediment load from the upper watershed. As the alluvial fan formed, coarser bed material such as cobbles and boulders dropped out first and smaller, finer material was carried further down the fan. The river became choked with sediment and shifted across the alluvial fan, in a process known as avulsion. The alluvial fan is shown in **Figure 2–5**.

Under existing conditions, Terrace Reservoir limits the amount of sediment entering the alluvial fan area. Sediment transported below the reservoir is obtained from the channel bed and banks. As the channel slope appears to be uniform in this reach, the majority of the material transported by the river likely comes from the channel banks. The area between Terrace Main Canal and Gunbarrel Road is a significant source of sediment transported downstream of Gunbarrel Road.

Irrigation diversions have also had an impact on the sediment loading in this reach. The reduction in flows during the irrigation season reduces stream power and sediment drops out to regain balance. If the diversion includes a dam across the channel, some deposition would also be expected upstream of the diversion due to the flattened slope and decreased stream power.

The median gravel bar sediment size for bars between Terrace Reservior and Gunbarrel Road is approximately 2.5 inches. The maximum size ranges from 12 to 15 inches, and the graphical mean ranges from 2.8 to 3.1 (**Figure 2–97**).

Figure 2–97. Middle Watershed Sediment Distribution Curves



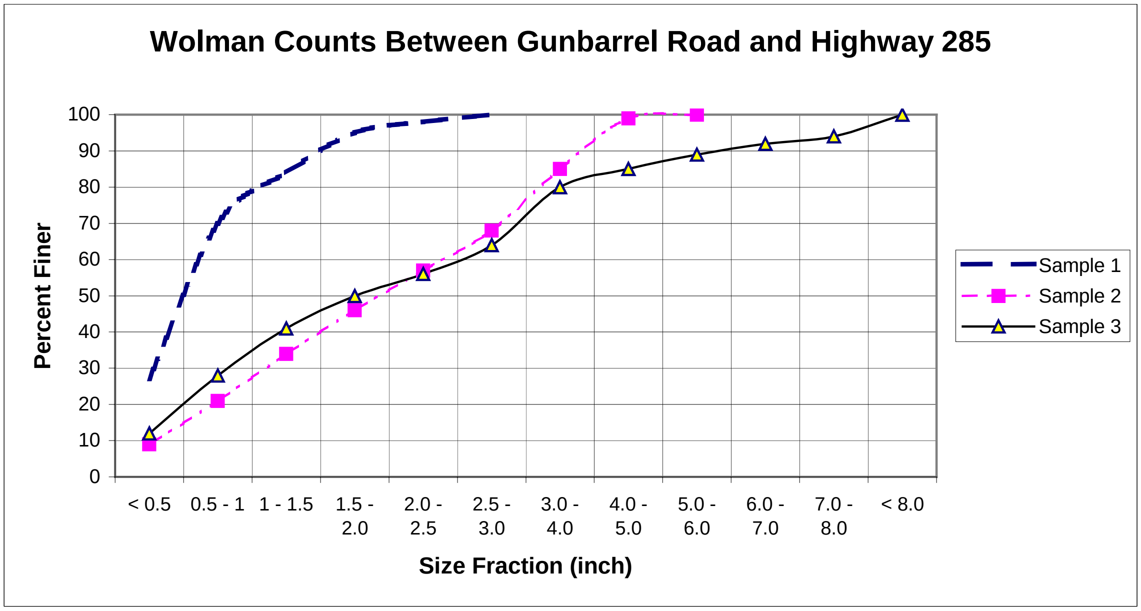
See sample locations in Figure 2–92

2.7.3 Gunbarrel Road to Highway 285

Under natural conditions, this reach of the Alamosa River would be expected to continually aggrade as the alluvial fan forms. Cobbles, gravel, sand and silts would typically deposit as the channel slope flattens out. Downstream of the irrigation diversions in this reach, aggradation has occurred as expected because there is less flow and the sediment transport capacity of the river decreases. In the straightened reaches, however, there is little aggradation due to the increased transport capacity of the channel. Some bed and bank erosion was observed through the straightened reaches. This erosion will continue in the straightened reach until the slope reaches equilibrium, at which point aggradation will occur. Downstream of the straightened reaches sediment has dropped out choking the channel resulting in channel stability problems. Aggradation and increased channel meandering is expected to occur in this reach as the channel adjusts to reach an equilibrium condition.

The median gravel bar sediment size varies from two inches near Gunbarrel Road to 0.75 inches near Highway 285. The maximum gravel bar sediment size varies from eight inches near Gunbarrel Road to three inches near Highway 285. The graphical mean ranges from 2.6 near Gunbarrel Road to 0.9 near Highway 285 (**Figure 2–98**).

Figure 2–98. Lower Watershed Sediment Distribution Curves



See sample locations in Figure 2–92

2.7.4 Sediment Quality

Rocky Mountain Consutants, Inc. (RMC) prepared a report for the Colorado Department of Public Health and Environment in 2000 which included information on sediment sampling done in Wightman Fork, the Alamosa River, and Terrace Reservoir. Samples were collected from both "in–channel" and "off–channel" or bank locations at the Wightman Fork and Alamosa River locations. Bottom sediments and shoreline deposits were collected at Terrace Reservoir. Approximately half of the sediment samples were submitted to a laboratory for total metals analysis. RMC also used field–screening tools such as X–Ray diffraction to establish a field correlation for metals content. The following tables summarize the metal concentration of samples collected at "in–channel' locations such as bars and the channel bed. The data reflect acid digested total metals based on US EPA M3050 digestion. These data provide a qualitative look at metals concentrations at three locations along within the Alamosa watershed.

Sediments at all three locations had elevated metals levels. The high concentrations of iron and aluminum are a reflection of the relatively low pH conditions of the water and sediment. Typically iron and aluminum will precipitate as an oxide, be complexed with organic matter and/or silts and will not remobilize unless there is additional lowering of the stream pH. At the time of sampling, the soils pH in Wightman Fork was below 5.0. This value was slightly higher in the Alamosa River. Lead, arsenic, cadmium, copper and zinc were also elevated. Exchangeable metals or the ability of these metals to resolubilize into the river was not addressed in this analysis, but given the high total concentrations, which are presented in the tables, one might assume that copper, lead and zinc may readily reenter an aqueous phase and continue to be transported downstream. These metals are highly dependent on the pH and redox potential of the water and any change in the chemical equilibrium conditions can remobilize the metals. Further laboratory testing would be necessary to establish the chemical exchange between the metals, which are complexed on the sediments and the aqueous environment within which they reside.

Table 2-27. Alamosa River Sediment Quality Data

Metals	WF0.0 (mg/kg)	WF1.1 (mg/kg)	WF2.1 (mg/kg)	WF5.5 (mg/kg)
Wightman Fork				
Aluminum	11,300	12,600	11,700	7,390
Arsenic	25.3	27.8	23.7	27.1
Cadmium	0.6	0.7	0.9	1
Copper	545	649	372	172
Iron	44,600	41,400	40,600	60,400
Lead	50	60	54	47
Manganese	798	603	583	662
Nickel	11	10	8	12
Zinc	177	158	130	158

Wightman Fork sample locations are stream miles increasing in the upstream direction. WF2.1 is 2.1 miles upsteam of the confluence with the Alamosa River.

Metals	AR21.6 (mg/kg)	AR31.0 (mg/kg)	AR34.5 (mg/kg)	AR34.9 (mg/kg)	AR37.5 (mg/kg)	AR38.4 (mg/kg)	AR41.2 (mg/kg)	AR42.7 (mg/kg)	AR43.6 (mg/kg)	AR44.3 (mg/kg)	AR45.5 (mg/kg)
Alamosa River											
Aluminum	11,200	11,400	10,100	10,100	12,100	8,810	10,600	10,200	11,300	10,100	14,300
Arsenic	10.8	6.4	8.2	10	7.5	10.9	6.3	7.8	9.6	9.3	5.5
Cadmium	1.7	2.2	0.7	1	0.9	1.2	1.7	1.6	1.2	0.6	0.4
Copper	239	307	208	307	378	147	87	75	201	129	26
Iron	65,800	60,200	39,100	34,000	56,200	40,700	64,300	66,700	59,600	44,100	47,300
Lead	28	17	21	26	27	21	20	19	25	30	23
Manganese	1,590	1610	412	956	834	442	586	466	485	381	350
Nickel	23	20	11	13	13	9	11	12	9	6	6
Zinc	97.2	198	135	188	180	120	113	103	86	57	56

Alamosa River sediment sampling locations are shown on **Figure 2–92**.

Metals	T005 (mg/kg)	T006 (mg/kg)	T007 (mg/kg)	T009 (mg/kg)	T010 (mg/kg)	T011 (mg/kg)	T014 (mg/kg)	T015 (mg/kg)	T016 (mg/kg)
Terrace Reservoir									
Aluminum	18400	19700	15500	28600	29700	28400	26500	27400	29600
Arsenic	15.2	18.5	15.5	29.4	38	32.6	17.6	21.7	25
Cadmium	4.1	3.7	3.8	7	7	8	5	6	9
Copper	590	582	520	1330	1490	1600	1050	1170	1380
Iron	47600	47400	38300	76500	94300	91200	69500	85700	103000
Lead	31	35	29	34	36	35	33	42	37
Manganese	440	396	304	1010	491	1250	1460	668	2780
Nickel	13	13	12	21	14	19	26	20	38
Zinc	169	163	168	241	212	275	345	294	476

Terrace Reservoir sample location descriptions:

T005 Terrace Reservoir in the Riverine Zone – SW bank
T006 Terrace Reservoir in the Riverine Zone
T007 Terrace Reservoir in the Riverine Zone – NW bank
T009 Terrace Reservoir in the Transition Zone – S bank
T010 Terrace Reservoir in the Transition Zone
T011 Terrace Reservoir in the Transition Zone – N bank
T014 Terrace Reservoir in the Lucustrine Zone – SE bank
T015 Terrace Reservoir in the Lucustrine Zone
T016 Terrace Reservoir in the Lucustrine Zone – NE bank

Comparison of the sediment quality with location in the Alamosa River is shown in **Figure 2–99** through **Figure 2–101** the one site upstream of Wightman Fork, AR45.5 allows for comparison of natural sediment quality with sediments potentially impacted by the Summitville site. The highest upstream sample location, AR45.5, is located just upstream of Wightman Fork and illustrates conditions in the watershed not impacted by Summitville. In some cases, sediment metal concentrations are lower at AR45.5 than at sites downstream of Wightman Fork, but not for all metals.

Figure 2–99. Sediment Aluminum and Iron Concentrations in the Alamosa River

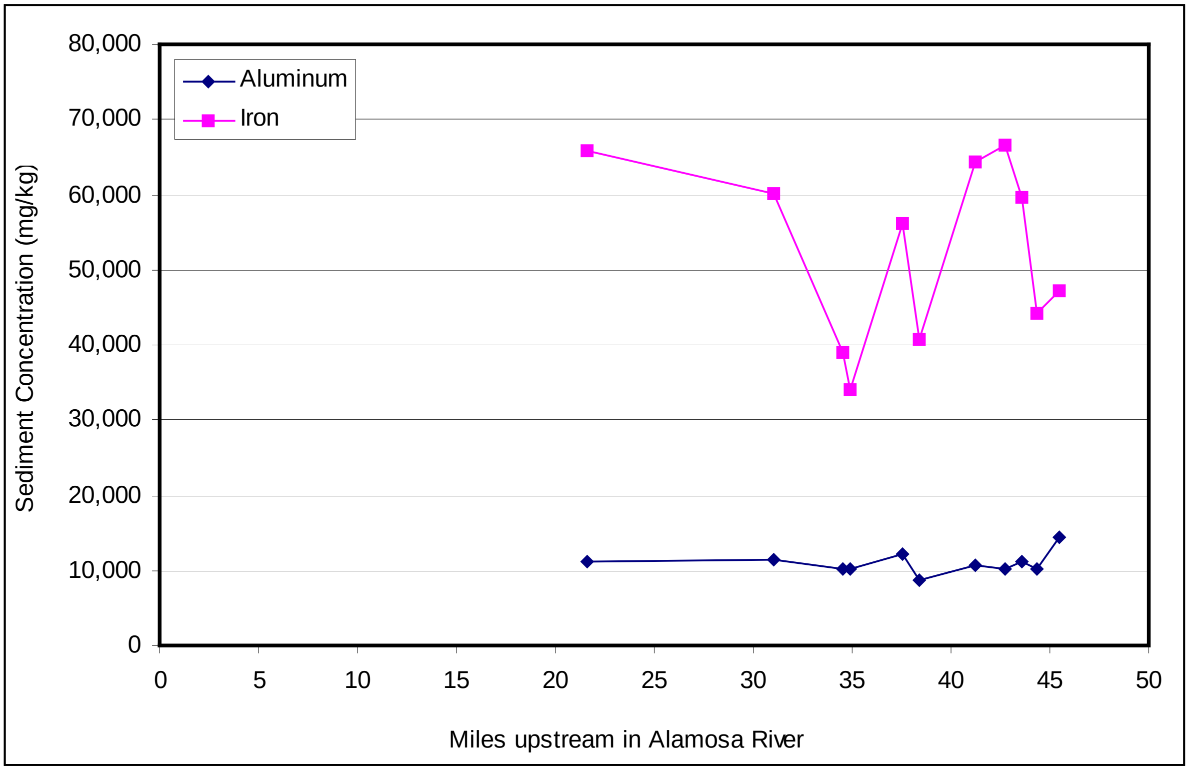


Figure 2–100. Sediment Zinc and Copper Concentrations in the Alamosa River

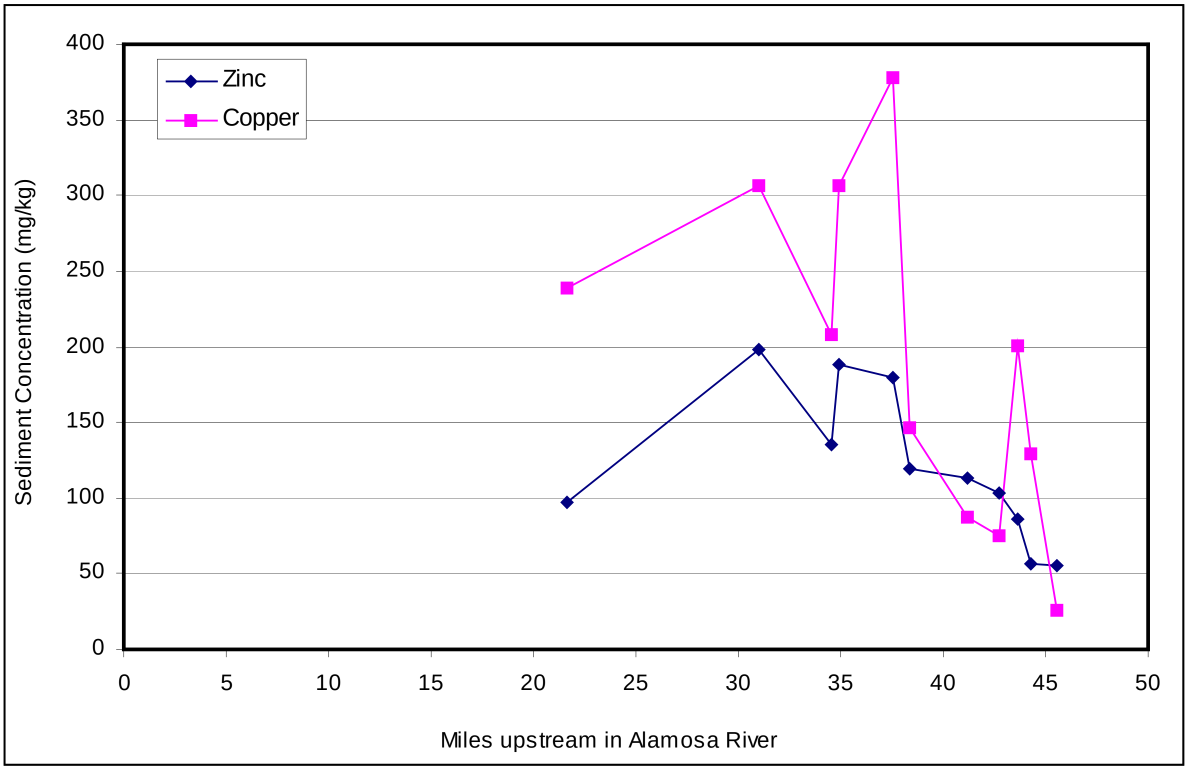
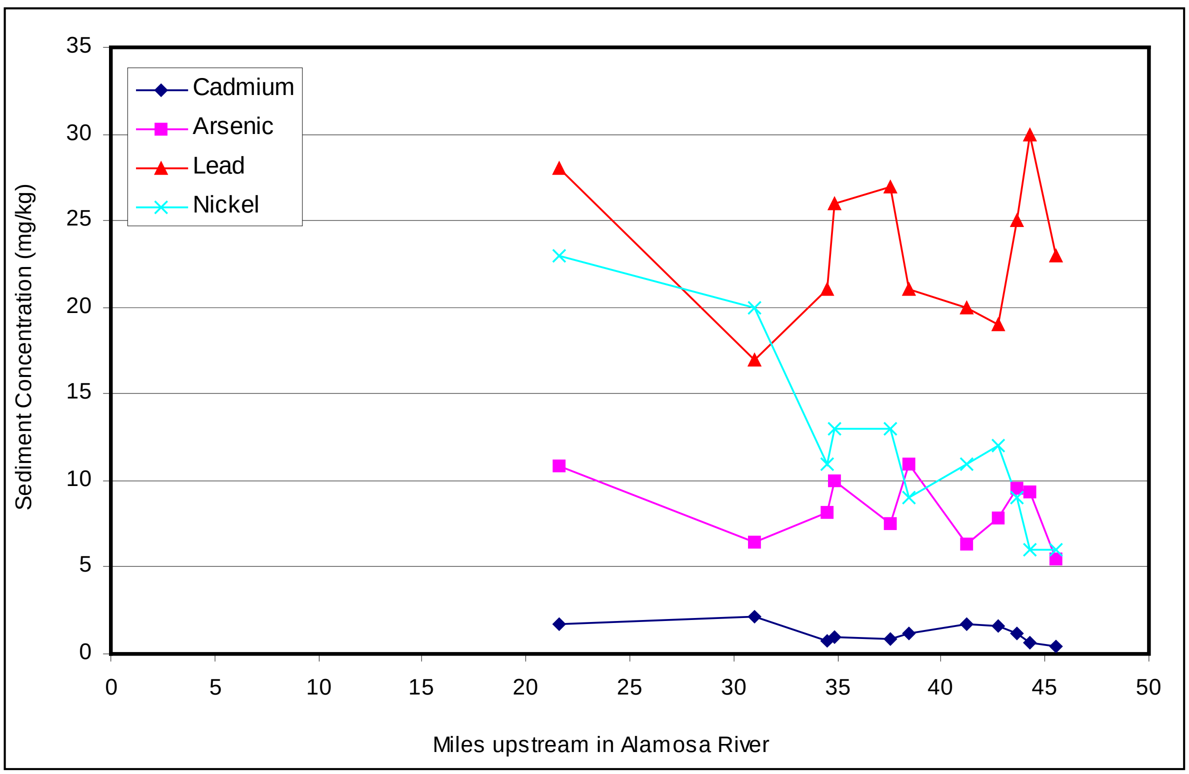


Figure 2–101. Sediment Cadmium, Arsenic, Lead, and Nickel Concentrations in the Alamosa River



2.7.5 Summary

The tributaries of the Alamosa River contribute a high sediment load to the Alamosa River. Terrace Reservoir captures the majority of the upstream sediment load. The river regains its sediment balance downstream of the reservoir, prior to entering the alluvial fan. Irrigation diversions and channel straightening have an impact on the sediment transport capacity. The results of the Wolman Pebble counts show large boulders and cobbles being transported in the upper watershed and at the head of the alluvial fan. Smaller material drops out as the river exits the alluvial fan downstream of County Road 10.

Based on a review of existing information the following key sediment transport issues were identified in the Alamosa River:

- There is naturally high sediment load from upper watershed.
- Terrace Reservoir captures upper watershed sediment.
- Irrigation diversions reduce the sediment transport capacity of the river.
- Channel straightening has changed the river's sediment transport capacity.
- Sediment quality studies indicate elevated levels of total metals within the watershed.

2.8 Riparian Habitat

The analysis of riparian habitat in the Alamosa River corridor was based on three components: riparian vegetation, fisheries, and riparian wildlife. These components were evaluated for each river segment and subwatershed. The investigation included the following aspects: current riparian vegetation composition; the effects of low flows, reduced groundwater levels, and impaired water quality on vegetation; aquatic ecosystem components, including fisheries; distribution and status of riparian–dependent wildlife; and current health of wildlife species, including species of particular significance to riparian habitat.

2.8.1 Riparian Vegetation

Current and historical aerial photographs, as well as USFS mapped vegetative coverages, were examined in an effort to characterize riparian vegetation in each subwatershed. Vegetative community type, distribution, condition, and connectivity are described to the extent possible based on existing information. A vegetative coverage map for each subwatershed is provided for reference in **Appendix E**.

Overall, riparian vegetation in the Alamosa River watershed is dominated by various willow (*Salix* spp.) and sedge (*Carex* spp.) species, Englemann spruce (*Picea engelmannii*)/subalpine fir (*Abies lasiocarpa*) complex, and mixed grasslands. In the lower reaches of the river, cottonwoods (*Populus* spp.) become the dominant woody species in the riparian corridor. Vegetative coverage is dependent on elevation, slope, aspect, and moisture regimes.

Segment T1 – Treasure Creek Subwatershed

The riparian character of Treasure Creek consists of small isolated patches of willow and forbland communities. Bare, rocky areas are present in this segment, which is likely a result of placer mining in the creek. These potential mining impacts have resulted in limited opportunities for vegetation growth.

Segment 12 – Treasure Creek to Iron Creek Subwatershed

In this segment, the Alamosa River flows through coniferous forest, and in some areas the forest creates a complete canopy over the stream. There are several waterfalls present in this segment. Riparian vegetation is composed of trees, shrubs, and grasses creating stable to moderately stable bank conditions. According to Rio Grande National Forest GIS data, patches of sedges are present in this segment; however, few willows are present.

Segment 11 – Iron Creek to Wightman Fork Subwatershed

In this segment, the Alamosa River generally runs through a narrow valley dominated by Englemann spruce/subalpine fir forest. Riparian grasslands are also present, as well as areas dominated by willows and roughstalk bluegrass (*Poa trivialis*). This corridor has incomplete connectivity due to an area of bare rocky land that is likely the result of historic placer mining activity.

Segments W1 toW4 – Wightman Fork of Alamosa River Subwatershed

The riparian habitat in Wightman Fork has been degraded due to impaired water quality from Summitville releases, natural mineralization, and excessive sedimentation due to placer mining activities.

Segment W4. In this segment, the banks are undercut along both sides of the stream. Slow moving runs deeply incised into the tundra characterize most of the visible portion of the stream. Bankside vegetation is composed of extensive coverage of grasses and sedges that in many areas completely cover the stream. Due to dense vegetation, the banks are stable and there is little erosion. Upland vegetation is said to completely canopy most of the stream, thereby shading the rocks, and reducing primary production (the production of biomass through photosynthesis). Just upstream of the confluence with Cropsy Creek, the fork is channelized and velocity increases. Since this segment is not canopy covered, primary production increases (Woodling 1995).

Segments W3 to W1. Shrubs are the dominant form of streamside vegetation along some portions of these segments, although in some areas, more than 50% of the stream bank has no vegetation. Several feet of bare rock is present between the edge of the water in the stream and the riparian vegetation. Where vegetation is present, it is dominated by willows and sedges, with some riparian coverage provided by Englemann spruce/subalpine fir, which is the dominant habitat overall in these subwatersheds. Woodling (1995) noted the presence of silt–like, orange iron precipitates that coated more than 50% of the stream bottom. From June 4, 1994 to July 29, 1994, the pH values of all ten samples from Wightman Fork were less than 4.0 (Mueller et al. 1996). The high acid level may have been responsible for decreased riparian vegetation (Woodling 1995).

Segment 10 – Wightman Fork to Jasper Creek Subwatershed

Riparian vegetation in this segment of the Alamosa River is composed of patches of willows, and other shrublands. Englemann spruce/subalpine fir also provide riparian coverage. Just west of Jasper Creek, the riparian corridor is lacking vegetation, and the river appears to have been subjected to placer mining in the past.

Segment 9 – Jasper Creek to Fern Creek Subwatershed

The western portion of this segment to Spring Creek is devoid of vegetation, according to USFS GIS data, most likely due to historic mining activities in the river corridor. Downstream of Spring Creek, the riparian corridor is fairly extensive, consisting of a mosaic of Englemann spruce/subalpine fir, patches of willow, sedges, roughstalk bluegrass, and aspen (*Populus tremuloides*) communities.

Segment 8 – Fern Creek to Beaver Creek Subwatershed

This segment of the Alamosa River appears to currently have an extensive healthy riparian corridor, with full vegetative coverage. The dominant communities are willow complex, sedges, and Englemann spruce/subalpine fir.

Segment 7 – Beaver Creek to French Creek Subwatershed
Riparian vegetation in this segment includes Englemann spruce/subalpine fir, other conifers such as Douglas fir (*Pseudotsuga menziesii*), willows, and aspen. The riparian vegetation reduces erosion and maintains fairly stable banks. In the vicinity of Beaver Creek, a winding oxbow is present, surrounded by fairly extensive riparian vegetation.

Segment 6 – French Creek to Terrace Reservoir Inlet Subwatershed
From French Creek to just past Phillips University Camp, the riparian corridor in this segment consists of a diverse assemblage of vegetative species, including willows, sedges, ponderosa pine (*Pinus* ponderosa), aspen, and Englemann spruce/subalpine fir, as well as various groundcover species. Downstream of University Camp, there is a lack of willows and other vegetation. This is mapped by the USFS, but the reason for the lack of vegetation is unknown.

Segment 5 – Terrace Reservoir Subwatershed
Vegetation surrounding Terrace Reservoir consists of rabbitbrush (*Chrysothamnus* spp.), fescue (*Festuca* sp.) grasslands, Douglas fir/white fir (*Abies concolor*) community, and other mixed grasslands and shrublands. There is no riparian corridor present in this segment due to fluctuating water levels.

Segment 4 – Terrace Reservoir Outlet to Terrace Main Canal Subwatershed
Small areas of this segment are shown to consist of riparian bluegrass vegetation. The dominant communities overall in this subwatershed consist of Douglas fir/white fir, rabbitbrush–dominated shrublands, and pinon pine (*Pinus edulis*) – juniper (*Juniperus* sp.) forest. Excessive sediment deposition associated with draining Terrace Reservoir is occurring in this segment, and is of concern to aquatic and riparian habitats.

Segment 3 – Terrace Main Canal to Gunbarrel Rd. Subwatershed
The dominant riparian tree species in this segment is cottonwood. Reduced groundwater levels and a dropping channel bed have damaged the existing riparian vegetation, including cottonwoods. Damage to riparian vegetation also has been caused by lack of winter flows. Continuous grazing of riparian pastures has increased weed species and non–native vegetation, and has reduced available downed woody debris. In some areas, cropland also encroaches on the riparian area.

Figure 2–102 shows a photo of dead cottonwood trees in the riparian corridor. The location of the dead trees was delineated from infrared photos taken in June 2004. Approximately 2.7 miles of cottonwoods were killed between Road 9 and the crossing with the Monte Vista Canal. **Figure 2–103** shows the location of the dead trees on an aerial photo.

In a United States Department of Agriculture (USDA)–Natural Resources Conservation Service (NRCS) riparian health assessment, portions of this segment were rated as healthy but with problems (USDA–NRCS 1997). Woody vegetation is considered good. The banks are stable and damage from a 1995 flood is healing. Middle age classes are underrepresented. Herbaceous vegetation is dominated by facultative plant species (species that equally likely to occur in either wetlands or uplands), with lesser percentages of facultative wetland (more likely to be in wetlands) and obligate wetland species (must be in wetlands). Small percentages of noxious weeds are present, including Canada thistle (*Cirsium arvense*) (USDA–NRCS 1997). Excessive sediment deposition associated with draining Terrace Reservoir is occurring in this segment, and is of concern to aquatic and riparian habitats.

Figure 2–102. Dead Cottonwood Trees in Riparian Corridor

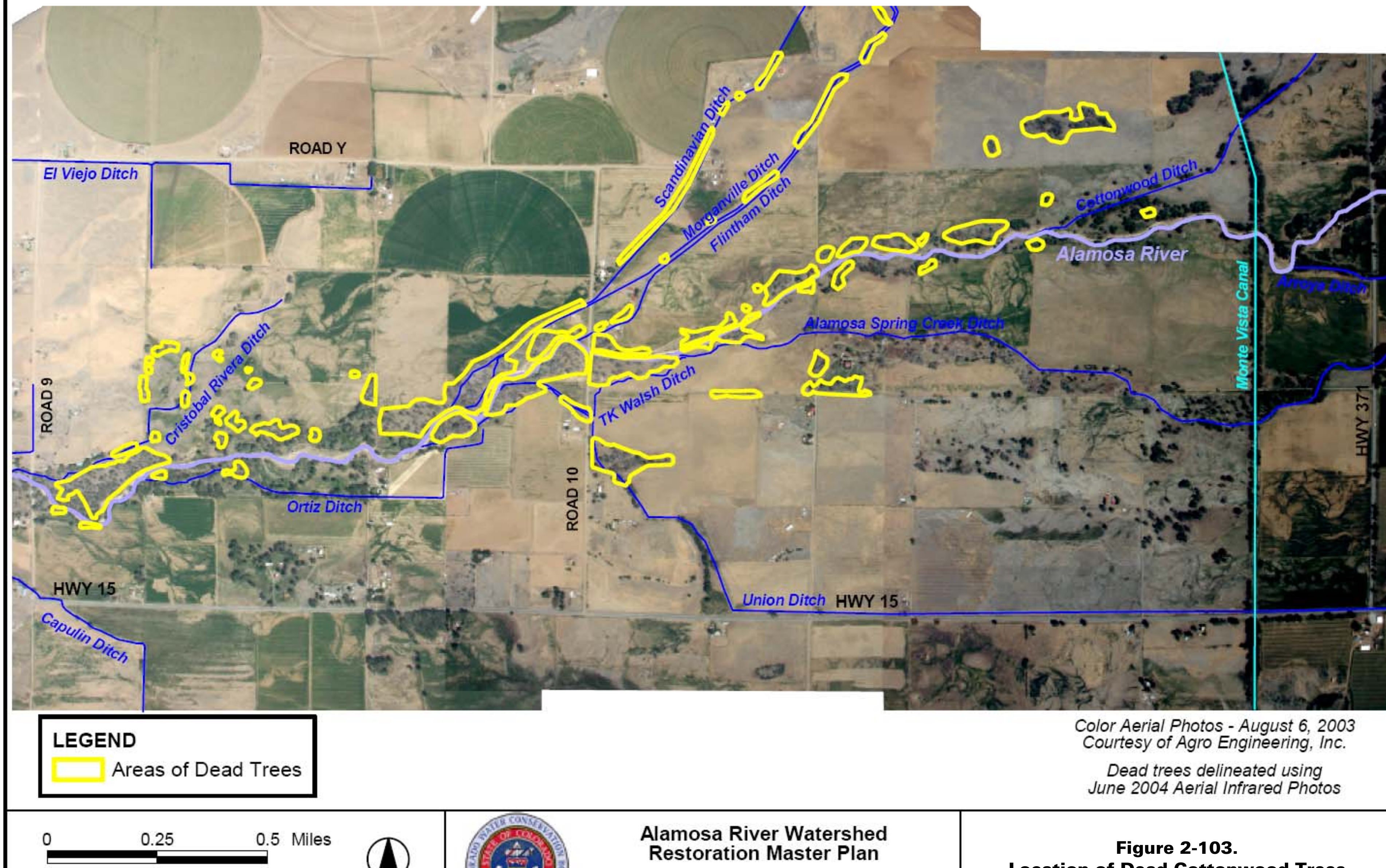
Segment 2 – Gunbarrel Rd. to County Rd. 10 Subwatershed

In this segment, reduced groundwater levels and a dropping channel bed have damaged the existing riparian vegetation, including cottonwoods. Damage to riparian vegetation also has been caused by lack of flood flows. Continuous grazing of riparian pastures has increased weed species and non–native vegetation, and has reduced available downed woody debris. In some areas, cropland also encroaches on the riparian area.

In a USDA–NRCS riparian health assessment study, this segment has a riparian evaluation rating of unhealthy (USDA – NRCS 1997). The extent of riparian vegetation in portions of the segment is limited by overgrazing, farming, low flows, and diking. Straightening, deepening, and levee construction due to flood control projects caused major bank erosion and a lower water table in this segment. Bare ground and significant stands of Russian knapweed are present, caused primarily by season–long overgrazing, which has converted woody vegetation to grass/forb communities. In many areas, vegetative coverage and root mass are inadequate to protect the banks from erosion (USDA – NRCS 1997). There is one primary age class of cottonwood trees that is growing older and is beginning to die out. Due to the combined impacts described above, young trees are not abundant. An Alamosa River Restoration project is ongoing in this segment; however, significant sedimentation has resulted in postponement of the project.

Segment 1 – County Rd. 10 to End Subwatershed

As in segment 2, reduced groundwater levels and a dropping channel bed have damaged the existing riparian vegetation, including cottonwoods. Damage to riparian vegetation has also been caused by lack of flood flows. Continuous grazing of riparian pastures has increased weed species and non–native vegetation and reduced available downed woody debris. In some areas, cropland also encroaches on the riparian area.



Color Aerial Photos - August 6, 2003
Courtesy of Agro Engineering, Inc.

Dead trees delineated using
June 2004 Aerial Infrared Photos

Alamosa River Watershed Restoration Master Plan

MWH in association with Agro Engineering, Lidstone and Associates, and SWCA

Figure 2-103.
Location of Dead Cottonwood Trees

In portions of this segment, riparian vegetation coverage is good; however, some sections are degraded by noxious weed infestation. Overgrazing of the riparian corridor and diking have limited woody vegetation growth (USDA – NRCS 1997).

2.8.2 Aquatic Ecosystem

Most information related to the aquatic biota in each subwatershed was compiled from a Colorado Division of Wildlife (CDOW) assessment completed by John Woodling in 1995. Any surveyed stream contained within the subwatershed boundaries defined by the Alamosa River watershed Restoration Master Plan map was included in the summary for that subwatershed. Stream reaches described by Woodling that have different boundaries than those of the restoration plan are described within each section. Tributaries are included within the appropriate subwatershed sections.

Segment T1 – Treasure Creek

Treasure, Prospect, Gold, and Cascade Creeks were generally treated as one unit during previous aquatic sampling. A reproducing population of Snake River cutthroat trout (*Oncorhynchus clarki behnkei*) was found in Prospect Creek in 1994 (Martin 1994). A population of adult Snake River cutthroat trout was also identified in Treasure Creek although that population showed no evidence of natural reproduction. The steep gradients of Gold and Cascade Creeks precluded colonization by fish (Woodling 1995).

Segment 12 – Treasure Creek to Iron Creek

Confluence of Treasure and Cascade Creeks to Iron Creek. In 1995, mayflies, stoneflies, and caddisflies dominated the macroinvertebrate community, comprising 59% to 69% of the taxa collected. Mayflies dominated the macroinvertebrate community, an indication that metals did not contaminate the stream (Woodling 1995).

Woodling documented the presence of Snake River cutthroat trout and brook trout (*Salvelinus fontinalis*) in this portion of the river in 1995. Almost all Snake River cutthroat trout collected were adults. Brook trout were collected in the vicinities of Gold Creek and Asiatic Creek. Brook trout collected near Gold Creek were all adult, and a variety of age classes was collected near Asiatic Creek. Reasons for lack of young age classes near Gold Creek was not determined, but absence of physical habitat was eliminated as a possible cause. Copper contamination spikes and metal dissolution were identified as a potential limiting factor for fish populations (Mueller et al. 1996).

Asiatic Creek. There was no data available regarding the macroinvertebrate community of Asiatic Creek. CDOW found a reproducing population of brook trout in the creek in 1995, comprised of at least three distinct age classes.

Iron Creek. The EPA sampled Iron Creek at its confluence with the Alamosa River in 1991 and found three crane fly larvae (Erioptera sp., Tipulidae) and two midge larvae (Orthocladinae, Chironomidae). This is a smaller amount of macroinvertebrates than would be expected in a healthy stream. In a normal Colorado stream, about two dozen taxa could be expected.

In 1991, a naturally reproducing population of Snake River cutthroat trout was identified in Iron Creek from the headwaters to a point just downstream of South Mountain Creek (Martin 1994). Woodling did not find any fish at the mouth of the creek in 1995. From August 5, 1994 through November 2, 1994, acid, aluminum, and copper levels were toxic to trout in the lower reach of Iron Creek. The absence of aquatic organisms in the lower reach of the creek was attributed in part to these water quality issues (Woodling 1995).

Segment 11 – Iron Creek to Wightman Fork

Between 1978 and 1994, the number of taxa and the proportion of mayflies did not change at the confluence with Iron Creek, but decreased by 90% downstream of Alum and Bitter Creeks. In 1978, the CDOW collected 38 brook trout from the river 0.5 mile downstream from the Iron Creek confluence. In 1993, two Snake River cutthroat trout and two brook trout were collected from this area. The populations of both species are reduced from those upstream of Iron Creek. One Snake River cutthroat trout was collected downstream of Iron Creek in 1994, and was thought to be dying. Fish are not present downstream of Alum and Bitter Creeks. One dead cutthroat was found under ice downstream of Alum Creek in 1996 by Mueller et al., and upon examination was found to have severe gill damage consistent with damage caused by high metal concentrations. Decreases in macroinvertebrate and trout populations are likely caused by increased heavy metal load (especially aluminum) and decreased pH from Iron Creek to Wightman Fork.

Alum Creek. No aquatic macroinvertebrates were found when the EPA sampled Alum Creek in 1994. No fish have ever been reported in Alum Creek. Physical habitat in Alum Creek is suitable to support an aquatic macroinvertebrate community. However, elevated metal concentrations (aluminum, copper, cadmium, and zinc) and low pH likely prevent their colonization. In addition to low pH and elevated metals, the general lack of cover in Alum Creek likely precludes fish colonization (Woodling 1995).

Bitter Creek. No aquatic macroinvertebrates were found when the EPA sampled Bitter Creek in 1994. No fish have ever been reported in Bitter Creek. The physical environment of Bitter Creek could support an aquatic macroinvertebrate community; however, elevated metal concentrations and low pH have prevented colonization. Acidic conditions and high metal concentrations in Bitter Creek are likely toxic to fish. Additionally, the lack of adequate flows in the stream would prevent fish use of Bitter Creek if water quality conditions were not limited (Woodling 1995).

Segments W1 toW3 – Wightman Fork of Alamosa River

Wightman Fork Above Cropsy Creek. Wightman Fork from the South Fork of Wightman to a point 0.25 mile upstream of Cropsy Creek was sampled in 1987 and 1994 (Horn 1988; EPA 1994). In 1987, the macroinvertebrate community was dominated by mayflies, stoneflies, and caddisflies (64% of taxa collected). The dominant species in 1987 was a beetle *(Heterlimnius corpulentus),* and seven species of mayflies were collected. There was little change in the macroinvertebrate community between 1987 and 1994. In 1994, 62% of the taxa collected were mayflies, stoneflies, and caddisflies. Five species of mayflies were collected and *Heterlimnius corpulentus* was still the dominant species. Chironomids were a significant portion of both collections.

In 1987, a reproducing population of 357 brook trout per acre (95% confidence intervals of 351 to 363 brook trout per acre) was identified in Wightman Fork 0.25 mile upstream of Cropsy Creek and downstream of Pipeline Creek (Horn 1988). In 1993, Woodling found only one brook trout in the same reach and estimated the population at 1% of its former size.

On September 16, 1993, the CDOW measured a total copper concentration of 5.9 μg/L, a pH of 7.1, and a total alkalinity of 6 mg/L (CDOW unpublished monitoring data). Woodling hypothesized that the reduced brook trout population was most likely an effect of the elevated copper concentration.

Wightman Fork Below Cropsy Creek. In 1987, the CDOW sampled macroinvertebrates at the mouth of Wightman Fork and noted only one adult aquatic beetle (*Heterlimnius corpulentus*) present at that time. A survey by the EPA in 1994 showed no aquatic macroinvertebrates present in Wightman Fork just downstream of Cropsy Creek. The EPA also surveyed Wightman Fork just upstream of the confluence with the Alamosa River in 1994 and found one stonefly (*Zapada* sp.), three mayfly nymphs (*Baetis* *bicaudatus*), and one caddisfly larva (*Rhyacophilia* sp.). In a normal Colorado stream, about two dozen taxa could be expected. Generally, the species of macroinvertebrates present in the mouth of Wightman Fork demonstrate low to moderate tolerance to poor water quality. However, Woodling noted that the presence of these species does not indicate improved water quality. Metal concentrations in the stream were high enough to induce immediate mortality so it is unlikely that the specimens collected had inhabited the area for any period of time. Rather, Woodling supposed that the species present had recently drifted into the sampling site.

No fish were found in Wightman Fork from Cropsy Creek to the confluence of Wightman Fork with the mainstem Alamosa River (Horn 1988, Woodling 1995). Woodling noted the presence of silt–like, orange iron precipitates that coated more than 50% of the stream bottom. By filling gravel interstices, these precipitates reduced macroinvertebrate habitat and trout spawning beds. From June 4, 1994 to July 29, 1994, the pH values of all ten samples from Wightman Fork were less than 4.0 (Mueller et al. 1996). During that period, the acidity of Wightman Fork from Summitville to the Alamosa River would have eliminated fish and aquatic macroinvertebrates. The high acidity level also may have been responsible for decreased riparian vegetation. In addition to the low pH values, aluminum, copper, cadmium, and zinc were all present in acutely toxic concentrations from downstream of Summitville to the Alamosa River.

Segment W4 – Wightman Fork Above Summitville

In 1994, Woodling sampled the macroinvertebrate community of the headwaters of Wightman Fork, west of Summitville. At that time, they found the stream dominated by terrestrial invertebrates. They attributed the low total number of taxa present, the low species richness, and the low percentage of mayflies in the stream reach to extensive shading of streamside vegetation and resulting reduced primary production.

Woodling documented a reproducing population of brook trout in this stream reach in 1994. The terrestrial macroinvertebrate food base, undercut bank refugia, and adequate flows make this habitat suitable for trout.

Segments 9 and 10 – Wightman Fork to Fern Creek

The number of macroinvertebrate taxa and organisms, and the percent of mayflies, in the Alamosa River decreased from Wightman Fork downstream to Silver Creek. Terrestrial organisms were the dominant group of macroinvertebrates. The CDOW found no fish in this stretch of river in 1993, and no fish sampling was conducted before 1993.

The lack of aquatic life in this stretch of river cannot be attributed to natural physical habitat. The authors attribute the decreased abundance to elevated levels of copper and aluminum, and low pH. Copper has been found to range from 10 μg/L to 3,000 μg/L in this stretch; 90 μg/L has been found to kill 50% of brook trout tested in 96 hours. For mayflies, 180 μg/L has been found to kill 50% of mayflies in a 14–day exposure, and 320 μg/L in 48 hours. Aluminum levels in the stream ranged from 2,309 μg/L to 6,714 μg/L; levels of 100 μg/L have been shown to be lethal to Snake River cutthroat trout at pH values less than 5.5. Overall, pH levels ranged from 4.4 to 4.9, levels that have been documented to limit the reproductive success of fishes. The low pH level is assumed to have decreased the numbers of mayflies, caddisflies, and stoneflies as well.

According to local residents, beaver have recently returned to this segment of the river. The return of this species should create more pools in the river, thereby improving physical fish habitat.

Jasper Creek. No data were available for the macroinvertebrate community of Jasper Creek. Due to intermittent flow, any macroinvertebrate community would be limited to taxa that are adapted for periods of desiccation. No fish were found in Jasper Creek when the CDOW sampled in 1995 due to lack of sufficient flow and channel drying.

The acidity of Jasper Creek would reduce macroinvertebrate abundance and diversity. Elevated copper and aluminum concentrations would preclude the development of a reproducing fish population even if adequate stream flow existed (Woodling 1995).

Burnt Creek. No data were available for the macroinvertebrate community of Burnt Creek. Due to intermittent flow, the community would be limited to taxa that are adapted for periods of desiccation. No fish were found during CDOW sampling in 1995 due to lack of suitable habitat caused by low flow conditions. Occurrences of pH levels toxic to aquatic macroinvertebrates occur in Burnt Creek and, when habitat is suitable, the stream may only be inhabited by acid tolerant species.

Segments 6 through 8 – Fern Creek to Terrace Reservoir Inlet

Alamosa River – Silver Creek to Terrace Reservoir. The macroinvertebrate community in the Alamosa River from Silver Creek to Terrace Reservoir was extremely depressed in numbers and diversity (Woodling 1995). Downstream of Burnt Creek, Woodling found only seven taxa and seven organisms present. In a normal Colorado stream, about two dozen taxa could be expected. Even the few organisms present may have drifted into the area.

Rainbow trout (*Onchorynchus mykiss*), cutthroat trout, and fathead minnows (*Pimephales promelas*) were collected just upstream of Terrace Reservoir in 1978. In 1990, the CDOW failed to collect any fish in the same stream reach. Absence of fish and aquatic macroinvertebrates in this reach of the Alamosa River was due to metal concentrations and/or acidity and was not related to physical habitat parameters (Woodling 1995).

Copper concentrations were acutely toxic to trout in the Alamosa River from Silver Creek to Terrace Reservoir from June 7, 1994 through July 9, 1994 (Woodling 1995). These copper levels exceeded the levels toxic to mayflies by a factor of 10. From June 2, 1994 to November 2, 1994, pH levels in this stream reach ranged from 4.4 to 6.5. Low pH levels likely limited fish reproduction in this reach. Aluminum was also potentially toxic to fish species during some parts of the year.

According to local residents, beaver have recently returned to these segments of the river. The return of this species should create more pools in the river, thereby improving physical fish habitat.

Segment 5 – Terrace Reservoir

There is no data for the aquatic macroinvertebrate community in Terrace Reservoir prior to 1990 although the population was adequate to support a rainbow trout fishery. From 1990 to 1995, sampling by the USGS and the EPA demonstrated a complete absence of macroinvertebrates in the reservoir. Plankton tows during that period revealed the presence of Copepoda (Cyclops), Cladocera (Daphnia), chironomids, rotifers, and protozoans (Bruce Marshall, Rocky Mountain Consultants, Inc., personal communication).

The CDOW stocked fish in Terrace Reservoir from the 1950s to 1990 (Bill Weiler, CDOW, personal communication). In 1975, cutthroat trout, rainbow trout, white sucker (*Catostomus commersonii*), and Rio Grande chub (*Gila pandora*) were found in the reservoir. The Rio Grande chub, a native species, was the most abundant organism at that time and the population was naturally reproducing. Based on the size of rainbow trout collected in 1975 and the lack of stocking in three previous years, it is likely that rainbow trout were also reproducing within or upstream of the reservoir. Despite consistent physical habitat, no fish were found in Terrace Reservoir in 1990 (Woodling 1995). Woodling attributed the disappearance of aquatic life in Terrace Reservoir to high levels of copper and increased acidity.

CDOW stocked rainbow trout in Terrace Reservoir in July 2001. In October 2001, the CDOW found several rainbow trout in the reservoir that were most likely a result of the stocking earlier in the summer but also may have emigrated from Silver Lakes. The same CDOW inventory also collected Snake River cutthroat trout, Rio Grande cutthroat trout, and Rio Grande chub. It is unknown how long the fish were residents of Terrace Reservoir but they most likely migrated into the lake from adjacent habitats after 1995.

Segments 2 through 4 – Terrace to County Rd. 10

Alamosa River downstream of Terrace Reservoir to diversion points upstream of Capulin. The upper portion of the river below Terrace Reservoir supported only one genus of caddis fly. This is likely due in part to the reservoir, which effectively halts invertebrate drift down the river. The lower portion of the river was dry at Capulin Ditch, which lies in subwatershed 2. No aquatic samples were collected, although if the river were to carry water it could support a macroinvertebrate community. Also, quiescent pupal staged or egg staged invertebrates may have been present if sampling had been conducted.

No fish were found in the Alamosa River below Terrace Dam by the CDOW in 1993. However, rainbow trout and Snake River cutthroat trout were periodically stocked in the river from 1953 to 1988, and locals maintain that this segment of the river was a healthy fishery before 1990.

The absence of aquatic life in much of the Alamosa River can be partially attributed to toxic metal loads and low pH. Below Capulin Ditch, aquatic organisms are reduced due to intermittent flow. Mueller et al. (1996) found that copper concentrations are higher below Terrace Reservoir than above the reservoir, at levels ranging from 7 μg/L to 1,449 μg/L from 1993 to 1995. Mueller et al. (1996) also found that pH levels ranged from 4.3 to 4.9 from July to November 1994. Generally, fish are unable to naturally reproduce at pH values below 5.5. Aluminum concentrations below the reservoir ranged from 300 μg/L to 7,437 μg/L from July to November 1994 (Mueller et al. 1996).

Segment 1 – County Rd. 10 to End

No macroinvertebrates or fish were present in this reach of the river, as this portion of river was dry at the time of sampling. No aquatic samples were collected, although if the river were to carry water it could support a macroinvertebrate community. Also, quiescent pupal staged or egg staged invertebrates may have been present if sampling had been conducted.

2.8.3 Riparian Wildlife

Key riparian dependent and closely associated wildlife species, including endangered, threatened, species of special concern, and sensitive species, are discussed below. The structural complexity and diversity of the riparian corridor affects utilization by these species, including opportunity for forage and cover.

Riparian habitats in Colorado have been documented to support at least 58 mammalian species. Those species include water shrew (*Sorex palustris*), western small–footed myotis (*Myotis ciliolabrum*), snowshoe hare (*Lepus americanus*), and mule deer (*Odocoileus hemionus*) (Fitzgerald et al. 1994). Beavers (*Castor canadensis*), a key indicator species, are discussed below.

The Alamosa River watershed also can be expected to support at least 13 riparian–obligate or dependent avian species. Those species are discussed in more detail in **Section 2.9**. The Southwestern willow flycatcher (*Empidonax traillii extimus*) and mallard (*Anas platyrhynchos*), key avian indicator species, are discussed below.

Two key indicator amphibian species are also discussed below. Amphibians and reptiles in the watershed are discussed in more detail in **Section 2.9**.

American beaver

By removing millions of beavers from streams and rivers during the 1820s–1840s, fur trappers also removed the small dams maintained by the beavers. These log dams, and the ponds behind them, slowed the passage of floods, trapped some sediment, and created a more diverse environment for aquatic and riparian organisms. Beaver were not observed in the Alamosa River during the late decades of the twentieth century. According to local residents, beaver have recently returned to the river upstream of Terrace Reservoir. The return of this species should create more pools in the river, thereby improving fish and amphibian habitat.

Southwestern willow flycatcher

The southwestern willow flycatcher is a riparian obligate species listed as Endangered by the USFWS and the State of Colorado. The upper elevational limit of the southwestern willow flycatcher is believed to be 9,000 feet. Though suitable vegetative coverage for willow flycatcher nesting is present in Segments 8 through 12, the elevation of these segments precludes use by the species. Segments 6 and 7 contain potential habitat for southwestern willow flycatchers. Despite suitable habitat present in this watershed, no southwestern willow flycatchers have been found in the area (USFS 2003).

Mallard

Mallards collected at Terrace Reservoir in 1995 had elevated copper concentrations in their livers (328 to 248 ppm) compared with duck livers from habitats such as the Alamosa National Wildlife Refuge. No recent data could be obtained on the status of elevated copper concentrations in mallards and other waterfowl species.

Boreal toad (mountain toad)

The boreal toad (*Bufo boreas boreas*) is listed as Endangered by the State of Colorado and is a candidate for federal listing. Breeding habitat of boreal toads includes lakes, marshes, ponds, and bogs with sunny exposures and quiet, shallow water. Beaver ponds create prime breeding sites for this species. The return of beavers to the Alamosa River should create more suitable habitat for the boreal toad upstream of Terrace Reservoir. No surveys for this species specifically in the Alamosa River watershed were identified for this analysis. Therefore, the current status in the watershed is unknown.

Northern leopard frog

The northern leopard frog (*Rana pipiens*) is listed as a species of special concern by the State of Colorado and is known to occur in Conejos and Rio Grande Counties. Typical habitats include wet meadows and the banks and shallows of marshes, ponds, glacial kettle ponds, beaver ponds, lakes, reservoirs, streams, and irrigation ditches. The elevational range of this species extends from below 3,500 feet to above 11,000 feet (Hammerson 1999). Within the Alamosa River watershed, potential habitat for this species may occur in each subwatershed, except where undercut banks preclude river shallows in Segments 1 through 4. No surveys for this species were found for this analysis. Therefore, the current status in the watershed is unknown.

2.8.4 Riparian Habitat Issues

Based on a review of existing information, the following key issues were identified as adversely affecting riparian habitat in the Alamosa River watershed:

- Noxious and non–native vegetation have become established in the lower Alamosa River.
- Overgrazing of the riparian corridor has degraded habitat in the lower Alamosa River.
- Placer mining has impacted the riparian corridor of the upper Alamosa River.
- Reduced groundwater levels, low flows, water quality, and sedimentation in the Alamosa River impact the quality of riparian vegetation.

2.9 Biological Resources

In order to interpret the overall suitability and health of wildlife habitat and populations in the Alamosa River watershed, selection of key indicator species is critical. Key indicator species are those species that appear critical to natural functions of particular biotic communities. Indicator species include threatened, endangered, and special status species, as well as common species. Indicator species within the study area are described below. Species have been selected from each vertebrate taxa. Aquatic macroinvertebrates have also been selected. Federally listed species are discussed in a separate section due to the management and protection considerations required for their survival.

2.9.1 Current Habitat Condition

Vegetative coverage types within the watershed include:

- mixed grasslands,
- willow communities,
- cottonwood – willow, aspen – birch (*Betula occidentalis*) forests,
- bristlecone pine (*Pinus aristata*),
- blue spruce (*Picea pungens*),
- Douglas–fir/mixed conifer forest,
- lodgepole pine (*Pinus contorta*)–dominant forest,
- pinyon – juniper, ponderosa pine (*Pinus ponderosa*)–dominant forest, and
- Englemann spruce/subalpine fir complex.

This diverse mosaic of communities at elevations ranging from 7,500 feet to 11,500 feet has the potential to support a variety of species.

Generally, upland conifer forests, which are the dominant habitats in the watershed, appear to be in good condition, based on an examination of 2000 and 2004 infrared aerial photographs and color photographs. Forest management practices are in place on USFS lands. Isolated impacts to potential wildlife habitat continue to occur in mined areas. Residential homes in the upper reaches of the watershed are sparse and have not appreciably altered potential habitat. Available habitat in the riparian corridor has been impacted by placer mining and excessive sedimentation; however, the majority of riparian habitat available for birds and mammals appears to be relatively good quality. In–stream aquatic habitat remains the most impacted component of the watershed.

Below Terrace Reservoir, the cottonwood–willow habitat along the lower segments of the watershed is currently in poor condition (USDA 1997). As discussed previously in **Section 2.8**, reduced groundwater levels and a dropping channel bed have damaged the existing habitat, especially cottonwoods. Damage to riparian vegetation also has been caused by lack of flood flows. Continuous grazing of riparian pastures has increased weed species and non–native vegetation and reduced available downed woody debris (USDA 1997). In some areas, cropland also encroaches on the riparian area. There is one primary age class of cottonwood trees that is growing older and is beginning to die out. Due to the impacts, young trees are not abundant. Use by riparian–dependent wildlife species currently appears to be limited by this condition. To the east of the study area, in the San Luis Valley, upland habitat consists primarily of croplands and rural areas.

2.9.2 Threatened and Endangered Species

The southwestern willow flycatcher, bald eagle, and Canada lynx are endangered species with potential to inhabit the Alamosa River watershed. Each species is discussed below.

Seouthwestern willow flycatcher

Southwestern willow flycatchers breed in riparian habitats in the southwestern United States and winter in southern Mexico, Central America, and northern South America. The USFWS listed the species as endangered due to widespread modification, fragmentation, and loss of streamside habitat; documented population declines; and lack of adequate protection. This loss of habitat is believed to be due to urban, recreational, and agricultural development; water diversion and impoundments; channelization; livestock grazing; and hydrological changes. Essential nesting habitat for the species includes areas of saturated soil or adjacent to surface water (streams or ponds) with an understory of shrubs or small trees (typically willow) and often an overstory of at least scattered larger trees.

According to the USFWS, the Alamosa River watershed is within the range of southwestern willow flycatchers, although no clear evidence has been shown to indicate that they are occurring there. Within this range, it is the current USFWS policy to protect all willow stands that are at least 30 feet x 30 feet in size with a minimum 5–foot tall average willow height. Critical habitat for this species is proposed to be designated by 2005. It is unknown at this time whether the Alamosa River corridor will be included in the critical habitat designation.

The USFS has identified potential habitat sites on the Rio Grande National Forest Conejos Peak Ranger District, which includes portions of the Alamosa River watershed. In 2002–03, Hawks Aloft, Inc. surveyed all identified potential habitat sites on this ranger district and found no southwestern willow flycatchers (USFS 2003).

Bald eagle

Bald eagles are listed as threatened by the USFWS and the State of Colorado. The CDOW has conducted standardized midwinter counts of bald eagles (*Haliaeetus leucocephalus*) throughout the state since the early 1980s, including four sites within the San Luis Valley. Although these counts do not provide actual population estimates, they do provide an index to general population trends and numbers. In general, bald eagle counts at most locations around the state have shown stable or growing populations over the past 14 years. Currently, there are no documented bald eagle nests in the vicinity of the Alamosa River watershed (NDIS 2004).

In the winter, white–tailed jackrabbits are bald eagles' primary food source. They also tend to concentrate in areas of abundant food supply, such as areas with high road–kills and winter fish–kills. Large numbers of eagles are present on the Alamosa National Wildlife Refuge in February and March prior to their spring migration. Based on the limited data available for eagle use along the Alamosa River corridor and extrapolation from data in other parts of the San Luis Valley, it appears that wintering populations in the watershed would be stable or increasing. However, cottonwood tree health and low fish populations likely limit eagle use of the lower Alamosa River. Improved cottonwood health and water quality are key to maintaining available habitat for this species in the watershed.

Canada Lynx

The Canada lynx (*Lynx lynx)* is a federally threatened and state–listed endangered species. Northern coniferous forests above 9,000 feet are the preferred habitat of the lynx. Uneven–aged stands with relatively open canopies and well–developed understories are ideal. Though suitable habitat exists for Canada lynx, according to the Colorado GAP Analysis model, there are no known occurrences of this species in the Alamosa River watershed (NDIS 2004). The last confirmed native lynx in Colorado was illegally trapped near Vail in 1972.

The CDOW began a Canada lynx reintroduction program in 1999, releasing cats into the south San Juan Mountains. The reintroduction program began with the release of 41 lynx in 1999, followed by 55 more in 2000 and 33 in 2003. Up to 50 more lynx will be released in 2005, and another 15 may be released in 2006 and 2007 (CDOW 2004).

2.9.3 Birds

Covering portions of the San Juan Mountains and the San Luis Valley, the Alamosa River watershed provides habitat for a diverse array of avian species. The study area is host to over 80 bird species (Kingery 1998). Although a discussion of the specific status and management needs for each of these species is not practical in this document, a discussion of the following groups of birds that are indicative of the overall health of the watershed is presented below:

- Riparian obligate or dependent bird species
- Raptors
- Waterfowl

Special status bird species, such as those listed as threatened, endangered, or species of special concern by the State of Colorado, are discussed in more depth.

Riparian Obligate or Dependent Bird Species

Riparian obligate or dependent bird species rely on a variety of microhabitats to thrive, including high–, middle–, and lower–elevation willow thickets, riparian coniferous forests, emergent wetlands and marshes, deciduous riparian forests, and open water areas. Riparian obligate bird species that are known to occur in the Alamosa River watershed include Wilson's warbler (*Wilsonia pusilla*), yellow warbler (*Dendrioca petechia*), Lincoln's sparrow (*Melospiza lincolnii*), and song sparrow (*Melospiza melodia*). Riparian dependent species include mallard, Cordilleran flycatcher (*Empidonax occidentalis*), tree swallow (*Tachycineta bicolor*), and MacGillivray's warbler (*Oporornis tolmiei*) (Kingery 1998; USGS 2004).

According to the Colorado Breeding Bird Atlas (Kingery 1998), all of these species have probable or confirmed evidence of breeding in or around the Alamosa River watershed. Of these species, the Lincoln's sparrow and Wilson's warbler are USFS Management Indicator Species. Protection of existing stands of willows, improvement in cottonwood health, and expansion of riparian vegetation are critical factors in the long–term existence of these species in the watershed.

Raptors

Raptors are high trophic level predators, and because of their sensitivity to environmental perturbations, they are considered indicators of ecosystem quality. Management to benefit raptors often protects a diversity of habitat, thereby providing benefits to a wide spectrum of other wildlife species. Raptors known to occur in the watershed include red–tailed hawk (*Buteo jamaicensis*), golden eagle (*Aquila chrysaetos*), American kestrel (*Falco sparverius*), and Swainson's hawk (*Buteo swainsoni*). In addition, the following raptors are state–listed species of special concern or federal agency sensitive species.

American peregrine falcon. The American peregrine falcon (*Falco peregrinus anatum*) is a state–listed species of special concern and is on the Colorado Natural Heritage Program (CNHP) list of imperiled species for Conejos County (CNHP 2004). They are known to occur in the Conejos Peak Ranger District of the Rio Grande National Forest. Breeding pairs of peregrine falcons nest on cliffs and forage over adjacent coniferous and riparian forests. Surveys conducted by the USFS in FY 2002 confirmed breeding on three nests within the Conejos Peak Ranger District, in which the Alamosa River watershed is located.

Ferruginous hawk. The ferruginous hawk (*Buteo regalis*) is a state–listed species of special concern, a BLM sensitive species, and is on the CNHP list of imperiled species for Conejos County (CNHP 2004). They inhabit grasslands and semidesert shrublands, and are occasionally found in pinyon–juniper woodlands. Breeding birds nest in isolated trees, on rock outcrops, on structures such as windmills and power poles, or on the ground. Grasslands, shrublands, and pinyon–juniper communities are present within the lower reaches of the Alamosa River watershed. The Colorado Breeding Bird Atlas does not document ferruginous hawks nesting in Conejos or Rio Grande Counties (Kingery 1998).

Northern goshawk. The northern goshawk (*Accipiter gentiles*) is a BLM and USFS sensitive species. This bird inhabits mostly conifer forests in Colorado, and do not seem to discriminate among tree species. They tend to choose nest trees on shallow slopes, flat benches in steep–country, and fluvial pans on small stream junctions. Aside from being a high trophic level predator, as builders of numerous, large nests, goshawks provide essential nesting opportunities for many species that cannot build their own nests. Thus, their presence is one indicator of forest health. Potential suitable habitat for northern goshawks is present throughout the Alamosa River watershed.

The Colorado Breeding Bird Atlas documents nesting goshawks in northern Conejos County and southern Rio Grande County in the vicinity of the study area (Kingery 1998). The USFS initiated a goshawk survey project in 2002. During that year, the survey identified eight territories, three active nests, and confirmed five fledglings in the Rio Grande National Forest (USFS 2003). However, it is unknown at this time whether goshawks are currently nesting in the Alamosa River watershed.

Waterfowl

As a whole, the San Luis Valley contains extensive waterfowl habitat in the form of marshes, ponds, lakes, rivers, streams, and other wetland and riparian areas. The most concentrated waterfowl use in the vicinity of the Alamosa River lies to the east in the Alamosa National Wildlife Refuge. Extensive use of the Alamosa River by waterfowl is unlikely, due to the lack of oxbows and marshes. There are a few lakes and small wetlands in the watershed that provide good quality habitat for waterfowl species that occupy montane areas, primarily mallard and green–winged teal (*Anas crecca*). Due to lack of riparian vegetation, Terrace Reservoir does not provide high quality habitat for waterfowl. Aside from the lack of physical habitat, the effects of elevated levels of metals and acids in the Alamosa River watershed on waterfowl is not fully understood. One study, described in **Section 2.8**, showed elevated levels of copper in the livers of mallard ducks using the Alamosa River.

The competition over available water between agricultural, residential, and wildlife uses plays an important role as to the amount of water available for sustaining waterfowl populations, notably in the lower segments of the watershed. Withdrawal of water from the river during the summer months is not beneficial to waterfowl since it is during their breeding season. The reduction of oxbows and marshes along the riparian corridor, coupled with water diversion, has undoubtedly had a negative effect on waterfowl populations in the watershed.

2.9.4 Reptiles and Amphibians

Amphibians, as well as some reptiles, are the most dependent taxa on environmental moisture. Their ranges, behavior, ecology, and life history are strongly influenced by the distribution and abundance of water. Amphibians and reptiles are key indicators of the health of both aquatic and terrestrial ecosystems. Historical analysis and monitoring of current populations is crucial to understanding the status of herptile populations in the Alamosa River watershed and San Luis Valley. Species likely to occur in the watershed include Western chorus frog (*Pseudacris triseriata*) and western garter snake (*Thamnophis elegans*). Indicator species, boreal toad and northern leopard frog, are discussed below.

Boreal toad (mountain toad)

Historically, the boreal toad occurred throughout most of the mountainous portion of Colorado, including Conejos County, and likely occurred within the Alamosa River watershed. The elevational range is generally 8,500 to 11,500 feet. Habitat for the boreal toad is moist conditions in the vicinity of marshes, wet meadows, streams, beaver ponds, kettle ponds, and lakes interspersed in subalpine forest (Hammerson 1999).

The boreal toad has undergone a severe decline in distribution and abundance in Colorado that is thought to have started in the 1970s. In the late 1970s, toads were reportedly easy to find in the San Juan Mountains; today they are scarce (Hammerson 1999). Several factors in combination are believed to have contributed to the decline of boreal toads and other amphibians. Contributing factors include increased UV light on embryos, acidification and heavy metal contamination of waters, habitat destruction and modification from various sources, impacts of introduced trout, climate change, predation, and others.

In the late 1990s, surveys of several hundred potential breeding sites within the historic range in Colorado indicated that the boreal toad has declined to extreme rarity in most of the state. Though potentially suitable habitat for the species appears to exist in the Alamosa River watershed, no populations of the boreal toad have been found recently in the area (NDIS 2004).

Northern leopard frog

The northern leopard frog, a state–listed species of special concern and a key indicator species for the area, was formerly abundant, but is now becoming scarce in many areas due to changes in habitat and predation by bullfrogs, a non–native species. Typical habitat of this species includes wet meadows, stream banks, and shallows of marshes and ponds. Diversion of water for irrigation probably has reduced the availability of breeding habitat along floodplains. The specific status of northern leopard frogs within the watershed is unknown at this time.

2.9.5 Mammals, Including Big Game

The diverse array of habitats within the Alamosa River watershed have been documented to support many mammal species, including coyote (*Canis latrans*), western spotted skunk (*Spilogale gracilis)*, long–tailed weasel (*Mustela frenata*), water shrew (*Sorex palustris*), raccoon (*Procyon lotor*), white–tailed jackrabbit (*Lepus townsendii*), snowshoe hare (*Lepus americanus*), mountain cottontail (*Sylvagus nuttallii*), porcupine

(*Erethizon dorsatum*), Botta's pocket gopher (*Thomomys boffae*), black bear (*Ursus americanus*), mountain lion (*Felis concolor*), and lynx (*Lynx rufus*).

Little information regarding historical population estimates or conditions is available for mammalian populations. It is certain that increased European settlement in the San Luis Valley caused changes to the local mammal populations and species diversity in the lower elevations of the Alamosa River watershed. In these subwatersheds below Terrace Reservoir, loss of habitat through landscape modification, the presence of human populations, and removal of forage or prey base are believed to be the main limiting factors to mammalian species. However, in the upstream subwatersheds, including areas of the Rio Grande National Forest, mammalian populations have not been directly disturbed by human activities to a great extent. In these upstream watersheds, it is unknown whether degraded water quality currently plays a role in mammalian population dynamics.

Key mammalian indicator species, based on importance to local environmental and economic health, include elk (*Cervus elaphus*), mule deer, and beaver. A discussion of these species is presented below.

Elk

The USFS lists elk as a management indicator species. Review of the CDOW's Natural Diversity Information Source database indicates that the entire watershed is within elk range. Portions of the watershed are severe winter range and others are summer range. Downstream of Terrace Reservoir, there is an elk wintering concentration. The area around Silver Creek is part of an elk migration corridor. Overall, elk populations are considered healthy throughout the watershed.

Mule deer

The USFS lists mule deer as a management indicator species. As a game species, along with elk, they provide a valuable economic and recreational resource to the area. Review of the CDOW's Natural Diversity Information Source database indicates that the entire watershed is within mule deer overall range. There are areas of mule deer summer range within the watershed. Lower elevation areas of the watershed are within mule deer severe winter range. In years of severe mountain weather, mule deer will heavily utilize that corridor. A portion of the watershed surrounding Terrace Reservoir has been determined to be a mule deer wintering concentration area. Overall, mule deer populations are considered healthy throughout the watershed.

American beaver

Beavers occur statewide in suitable habitat, marked by adequate supplies of water and food, whether in the alpine zone or on the eastern plains. Beavers are capable of invading reservoirs, canals, and irrigation ditches as long as food resources are available. In Colorado, beavers are common in areas with abundant aspen, cottonwood, or willow, especially in broad glacial valleys with low stream gradients. Beaver were not observed in the Alamosa River during the late decades of the twentieth century. According to local residents, beaver have recently returned to the river upstream of Terrace Reservoir. The return of this species indicates improved water and food conditions in the watershed. Beavers returning to the Alamosa River should create more pools, thereby improving fish habitat.

2.10 Fishes

Fish Species of Concern

Fish species of concern including the Rio Grande sucker, Rio Grande chub, and Rio Grande cutthroat are discussed below.

Rio Grande sucker. The Rio Grande sucker (*Castomus plebeius*) is a USFWS species of concern and a BLM sensitive species. This species is most common in tributary streams and is generally absent from the Rio Grande. The last intensive survey of the Rio Grande above Bernalillo, New Mexico found Rio Grande sucker only at two sites – the confluence of the Rio Chama in Espanola and the confluence of the Santa Fe River (Platania 1991). Rio Grande sucker was listed as endangered by the State of Colorado in 1993 when it was discovered that only one small population (Hot Creek) remained in the state. Since then, the CDOW has reintroduced Rio Grande sucker to several Rio Grande tributaries and continues to maintain a broodstock at their Native Aquatic Species Restoration Facility.

This small–bodied fish occupies cool, middle elevation (6,500 to 8,500 feet) streams flowing over gravel, cobble, and other rocky substrates. It is rarely found in waters with heavy loads of silt and organic detritus (Sublette et al. 1990). The Rio Grande sucker is a benthic feeder that scrapes periphyton from rocks and consumes molluscs, macroinvertebrates, and annelids.

The introduced white sucker (*Catostomus commersoni*), now one of the most abundant fishes in the upper Rio Grande, has displaced the Rio Grande sucker from the Rio Grande and many tributaries. Hybridization of Rio Grande sucker with white sucker also may have led to the decline of the Rio Grande sucker. Historically, the Rio Grande sucker was not found in the Alamosa River (Woodling, 1995) possibly due to the presence of the white sucker.

Rio Grande chub. Rio Grande chub (*Gila pandora*) is native to the Rio Grande drainage. This small, robust minnow is now found sporadically throughout the Rio Grande and its tributaries north of Bernalillo, New Mexico (Sublette et al. 1990). In mainstem Rio Grande habitats, the range of the species has contracted in the past 50+ years. In most tributary streams of historic occurrence, its abundance appears to be fairly stable (NMDGF 1994). Colorado and Texas each have a single population (NMDGF 1994). The Rio Grande chub is listed as a species of special concern by the State of Colorado and its population is limited to Hot Creek.

This species is found in impoundments and pools of small to moderate streams and is frequently associated with aquatic vegetation (Woodling 1985). It appears to prefer pools and pool–runs in association with cover (NMDGF 1994). Rio Grande chubs occupy perennial mainstream and tributary habitat at higher elevations (Bestgen and Platania 1990). The species is a midwater carnivore that feeds on zooplankton, aquatic insects, and juvenile fish. It also takes a limited amount of detritus (Woodling 1985).

Stocking nonnative fishes, bank degradation, water diversion, and the lowering of water quality in the Rio Grande drainage have led to a drastic decline in the number of chubs in Colorado since the 1800s. The removal of "rough", or undesirable, fishes by the CDOW to help sport fish production has led to the inadvertent demise of this fish. Rio Grande chubs are known to hybridize with longnose dace and require riffle habitat for spawning. Four Rio Grande chubs were collected in Terrace Reservoir in 2001. According to CDOW, it appeared that the chubs had moved into Terrace Reservoir within the 6 years prior to that sampling event (CDOW 2001).

Rio Grande cutthroat. The Rio Grande cutthroat *(Oncorhynchus clarki virginalis)* is a USFWS species of concern and a BLM sensitive species. The species is not listed at the state level. The Rio Grande cutthroat trout once ranged over much of the upper Rio Grande basin in New Mexico and southern Colorado. The subspecies is believed to have evolved from the Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) and is closely related to the Greenback cutthroat trout (*Oncorhynchus clarki stomias*). Native populations of Rio Grande cutthroat trout occur in the headwaters of the Rio Grande in southwestern Colorado and in headwaters of four drainages in New Mexico; the Rio Grande, the Pecos, and the Canadian, including the Mora. Streams occupied by Rio Grande cutthroat trout are, for the large part, small headwater streams where productivity is low, stream gradients are high (> 4%), and connectivity to other tributaries is almost nonexistent (Calamusso and Rinne 2004). The historic range of the Rio Grande cutthroat trout likely encompassed all cool waters in the Rio Grande drainage, including the Chama, Jemez, and Rio San Jose drainages, along with suitable waters of the Pecos River basin (Stumpff and Cooper 1996). Stumpff and Cooper (1996) speculate that this distribution may have covered approximately 40 hydrologic sub–basins in Colorado and New Mexico. Currently, there are 114 extant populations of Rio Grande cutthroat trout in Colorado and New Mexico, occupying approximately 5% of their former range (Alves 1998; NMDGF 1997; Harig and Fausch 1996; Stumpff and Cooper 1996). In Colorado, of the 68 historic or transplanted Rio Grande cutthroat trout populations documented since 1982, 18% have been extirpated and 43% are considered unstable (Harig and Fausch 1996). In New Mexico, only 11% of the 54 populations are considered stable (Stumpff and Cooper 1996). There is no available information specific to the Rio Grande cutthroat in the Alamosa River, other than the fish collected in Terrace Reservoir.

Like most native trout, Rio Grande cutthroats are imperiled for a number of reasons. Introduced fish species prey on native trout and often out–compete natives for available resources, particularly food. Native cutthroat populations are genetically diluted through crossbreeding with introduced rainbow trout. Logging, mining, land development, grazing, and agriculture have all contributed to the destruction of cutthroat habitat. Over–harvesting due to sportfishing for cutthroat can also impact their populations.

One Rio Grande cutthroat trout was collected in Terrace Reservoir in 2001. According to CDOW, the collected fish was a migrant from Rough Canyon (CDOW 2001).

Other Fish Species

Fish species that could potentially inhabit the Alamosa River watershed are discussed below.

Longnose dace. The longnose dace (*Rhinichthys cataractae*) is an extremely widely distributed fish, ranging throughout most of Canada, south to Washington, east to New York, and south again through the Appalachians to Tennessee, throughout the Rocky Mountains, and to Texas (Scott and Crossman 1973). In Colorado, the species is native to the Arkansas, Rio Grande, Republican, and Platte Rivers (Ellis 1914; Propst 1982). The status of longnose dace populations is stable in the Rio Grande, Pecos, and Canadian drainages (Sublette et al. 1990). To the best of our knowledge, longnose dace have not been found in the Alamosa River.

Longnose dace are usually found in clear, clean waters although they can tolerate some degree of organic enrichment. They prefer riffle habitats with gravel or rubble substrate (Woodling 1985). A benthic omnivore, the longnose dace feeds principally on chironomids, mayflies, and simuliids, but also takes algae and plant material.

Brown trout. Brown trout *(Salmo trutta)* are native to Europe. They were brought to Colorado in 1903. Brown trout are the most aggressive of the introduced trout, and their adult diet consists mostly of fish. As a result, brown trout generally impact the populations of other conspecifics, fish of the same species.

Brook trout. Brook trout *(Salvelinus fontinalis)* are native to the eastern United States. They were brought to Colorado in 1882. Brook trout are able to colonize small, headwater streams where they often outcompete native trout due to differences in feeding behavior. They have a higher range of tolerance for many metals and pollutants than many other fish, and as a result, are often the only species present in impacted stream reaches. Brook trout were collected in the Alamosa River above Iron Creek in 1993 (Woodling 1995).

Rainbow trout. Rainbow trout *(Oncorhynchus mykiss)* are not native to the western United States. They were brought to Colorado by gold miners in the late 1880s. Rainbow trout readily hybridize with native cutthroats and are one of the primary threats to conservation of native salmonids. Since their introduction, they have become the most commonly stocked fish species in the state of Colorado. Rainbow trout were stocked in Terrace Reservoir in 2001. In a September 2001 sampling event, CDOW collected 147 rainbow trout from the reservoir. The trout appeared to be in good physical condition, and the sampling showed that rainbow trout stocked after snowmelt survived and increased in size (CDOW 2001).

Snake River finespotted cutthroat. The present known distribution of the Snake River cutthroat *(Oncorhynchus clarki behnkei)* in its native range includes the Snake River drainage from below Jackson Lake, Wyoming downstream to Palisades Reservoir, encompassing all tributaries from the Gros Ventre River to the Salt River. The subspecies is popular with anglers due to its vigorous fight on the line. The finespotted cutthroat has also proven to be highly adaptable to a wide range of conditions. As a result, it is the most widely propagated subspecies of cutthroat and is the most widely stocked outside its native range (Behnke 2002). Snake River cutthroat were collected in the Alamosa River upstream of Wightman Fork in 1993 and 1994 (Woodling 1995). One Snake River cutthroat was collected from Terrace Reservoir in 2001. CDOW hypothesized that the individual came from 1995 plants in the Alamosa River upstream of Wightman Fork, Treasure Creek, or Prospect Creek (CDOW 2001).

Fathead minnow. The fathead minnow *(Pimephales promelas)* is native to central North America, northeastern United States, and northeastern Mexico. In Colorado, the fathead minnow is native to the eastern slope of the Rockies. Through bait bucket transfers and other accidental introduction, the fathead minnow is now found in waters throughout the western portions of Colorado. The fathead minnow may now be the most widely distributed fish in Colorado, inhabiting nearly every drainage in the state.

Fathead minnows are tolerant of extremes in environmental conditions, able to withstand high temperatures, high nutrient concentrations, low dissolved oxygen levels, high turbidity, and fairly stagnant conditions (Bestgen and Platania 1990). The fathead minnow is found in a wide variety of habitats in rivers, streams, lakes, and ponds, particularly in waters with abundant floating and submerged vegetation (Sublette et al. 1990). They feed in soft bottom mud, taking a variety of items from algae and plant fragments to insect larvae and microscopic crustaceans, depending on the food available (Sublette et al. 1990). Fathead minnows were collected above Terrace Reservoir in 1975 and below Terrace Reservoir in 1984–85 and 1993 (Woodling 1995).

White sucker. The white sucker *(Catostomus commersoni)* is widespread in North America. It occurs south from the Arctic Circle in the Mackenzie River drainage through the Mississippi and Atlantic drainages to approximately the 35th parallel. It is absent from much of the Pacific slope. The white sucker was most likely introduced to the Rio Grande basin as a baitfish. The species inhabits lakes, streams, and rivers, usually above 4,500 feet elevation. Pools with logs, brush, or other cover are preferred habitats (Sublette et al. 1990).

White suckers are benthic omnivores consuming plankton, crustaceans, and other invertebrates as well as detritus and plant material. Feeding occurs mostly at night (Sublette et al. 1990). This species is highly fecund and often dominates a body of water. Fishery managers, therefore, sometimes reduce the number of white suckers in lakes (Sublette et al. 1990). Often used as a bait fish, white suckers have been introduced into many high elevation lakes and streams. Once established, sucker populations become overly abundant while trout diminish (Woodling 1985). Hybridization with white suckers has been proposed as one reason for the decline of native Rio Grande suckers in the basin. White suckers were collected in Terrace Reservoir in 1975 and in lower segments of the Alamosa River in 1984–85 and 1993 (Woodling 1995).

Common carp. Native to Europe, carp (*Cyprinus carpio*) were introduced as a food fish by settlers during the 1800s. Carp are now found in warm, slow–moving water throughout North America. In Colorado, they inhabit most warm water impoundments and rivers across the state.

Benthic omnivores, carp suck up lake bottom sediments, remove any edible invertebrates and plant material, then expel the mud. This feeding behavior uproots aquatic vegetation, increases turbidity, and disrupts the spawning of other species. Carp also transfer nutrients from lake sediments to the water column through their digestive tract, promoting conditions that favor phytoplankton growth over that of rooted aquatic macrophytes. Carp are extremely fecund and often come to dominate habitats where they are introduced. Carp were collected in lower sections of the Alamosa River in 1984 and 1993 (Woodling 1995).

Brook stickleback. The brook stickleback (*Culea inconstans*) occurs from the Yukon Territory eastward to Nova Scotia and southward to British Columbia, Nebraska, Illinois, and Ohio, with disjunct populations southward to New Mexico (Lee and Gilbert 1978), Tennessee, and Alabama (NMDGF 1988). There is some question as to whether the species is native to Colorado or whether current populations are the result of accidental bait bucket transfers.

This species prefers clear, cool, heavily weeded, spring fed lakes and ponds, as well as low–gradient streams (NMDGF 1988). The brook stickleback is primarily carnivorous, feeding principally on insects, especially Chironomidae, crustaceans, and the eggs and fry of fish, but it also takes algae. Brook sticklebacks are also known to feed on the eggs and larvae of other species (Scott and Crossman 1973). Brook sticklebacks were collected in the Alamosa River at U.S. Highway 85 in 1993 (Woodling 1995).

Fishery Viability

The examination of the viability of fisheries within the watershed is a good method for assessing the condition, health and stability of the watershed ecosystem. Fisheries can be an indicator of water chemistry, degree of sedimentation and loading, stream morphology, riparian health, and surface water availability. The absence, presence, and productivity of fisheries in the watershed may give an indication of current and historic watershed and river conditions. The Alamosa watershed is unique and has varying degrees of natural and anthropocentric disturbances that potentially restrict fisheries. These limiting factors vary by sub–watershed and current and historic environmental conditions.

One of the earliest scientific accounts of fish distributions in the watershed was in 1889 when four species of fish were identified in the San Luis Valley at two separate locations (Jordan 1891). Fisheries that were documented in the Alamosa River prior to mining indicated that naturally occurring metal concentrations did not prohibit trout productivity in the entire River (Jordan 1891, Woodling, 1995). Fishery and water quality sampling in some tributaries of the Alamosa River indicate naturally and human induced factors that limit fishery productivity. The CDOW samples areas around the state as part of wildlife programs. In 1975, the CDOW sampled the fish population in Terrace Reservoir prior to the Galactic Summitville operation and found four species of fish: rainbow trout, cutthroat throat, white sucker, and Rio Grande chub. In 1978, sampling upstream from Terrace Reservoir indicated the presence of rainbow trout and cutthroat trout (Woodling, 1995). That same year sampling in the River between Wightman Fork and Bitter Creek indicated the absence of fish probably from toxic metal concentrations in that stream reach (Woodling, 1995). Just upstream at Stunner Campground during the same year, sampling indicated a viable population of brook trout and Snake River cutthroat. According to fish sampling in 1987, a brook trout population was present upstream of Summitville in Wightman Fork. In 1993, sampling in this same reach resulted in one fish compared to 26 in 1987 (Woodling, 1995). CDOW sampling in Wightman Fork downstream from the Summitville operation in 1987 demonstrated that no fish were present. Wightman tributaries were investigated in 1993 and 1994. No fish were found in Sawmill Ck., Palmer, Whitney and Smallpox Gulches. Natural habitat, not water quality, was determined to be the limiting factor for fisheries in these reaches.

Fish stocking was done by CDOW in Prospect and Treasure Creeks in the early 1990's. Sampling in these reaches indicated that seasonal water quality relating to snow melt and natural metal concentrations may be a cause of reproductive failure in the younger more susceptible fish, thus limiting fishery productivity (Woodling, 1995). Iron Creek was sampled in 1994. Sampling in this reach indicated a fish population; however water quality may limit natural reproduction (Woodling, 1995). A naturally reproducing fishery population has been documented between Gold Creek and just upstream from Alum Creek. Angler reports also document fisheries in Gold, Cascade, and Asiatic Creeks (Woodling, 1995). Woodling also attributes the lack of fish in Alum and Bitter Creeks to a combination of acidity, metals and physical habitat. In 2001, CDOW released trout in Terrace Reservoir to document growth and survival rates. Additional fish inventories in 2002 affirmed that upstream water quality had improved enough to potentially support a limited fishery in the Reservoir. Downstream of the Reservoir water availability and lack of suitable physical habitat continue to limit fishery production.

2.10.1 Key Biological Resources Issues

The following are key issues of concern for biological resources that should be addressed by the Master Plan:

- Impaired water quality in the Alamosa River adversely effects biological communities.
- Fish populations cannot be maintained in the lower Alamosa River due to lack of flow.
- Lack of oxbows and floodplain in the Alamosa River limit habitat values.
- Cottonwood health has been degraded by low groundwater levels and lack of overbank flows in the lower watershed.
- Introduced fish species, such as carp, displace native fishes.

2.11 Agricultural Uses

A large area of agricultural land relies on the water of the Alamosa River. Agriculture was impacted by open pit mining at Summitville and the resulting degradation of water quality. Agriculture has also been impacted by channel straightening and deterioration of natural river function. Eroding banks and channels have impacted headgates and the ability to divert water from the river. Ground water tables have dropped near the river in several reaches and impacted irrigation water supplies and riparian vegetation. This section examines impacts to agriculture due to these problems in the Alamosa River.

2.11.1 Agricultural Resources

Agriculture is important to the communities in and around the Alamosa River watershed. Farming and ranching provide employment, revenue, and a cultural heritage for a large portion of the watershed's residents. Residents outside of the watershed also rely on the Alamosa River due to canals that transport water to adjacent watersheds. Conejos County is considered the second poorest county in Colorado and has a relatively high unemployment rate. Farming accounts for approximately 24% of the employment in Conejos County as a whole (CCSCD 1997), but is the primary employment resource in the Alamosa River watershed.

Figure 2–104 shows areas irrigated by Alamosa River watershed surface and ground water. Approximately 53,300 acres are irrigated at least in part by Alamosa River water (Agro Engineering 2000). **Table 2-28** shows the acreage of crops irrigated in 1998. Grass hay, alfalfa, and small grains are the primary crops grown in the area along with a small amount of potatoes, spinach, and lettuce. A large area of meadow pasture is used for cattle grazing near the lower end of the Alamosa River. In 2003, 147 center pivot sprinklers covering 16,873 acres were used to irrigate land within Alamosa River ditch service areas (Agro Engineering 2004). The remaining area is irrigated using flood irrigation. Use of sprinkler irrigation is increasing; 19 sprinklers were installed in the Alamosa River area between 1998 and 2003.

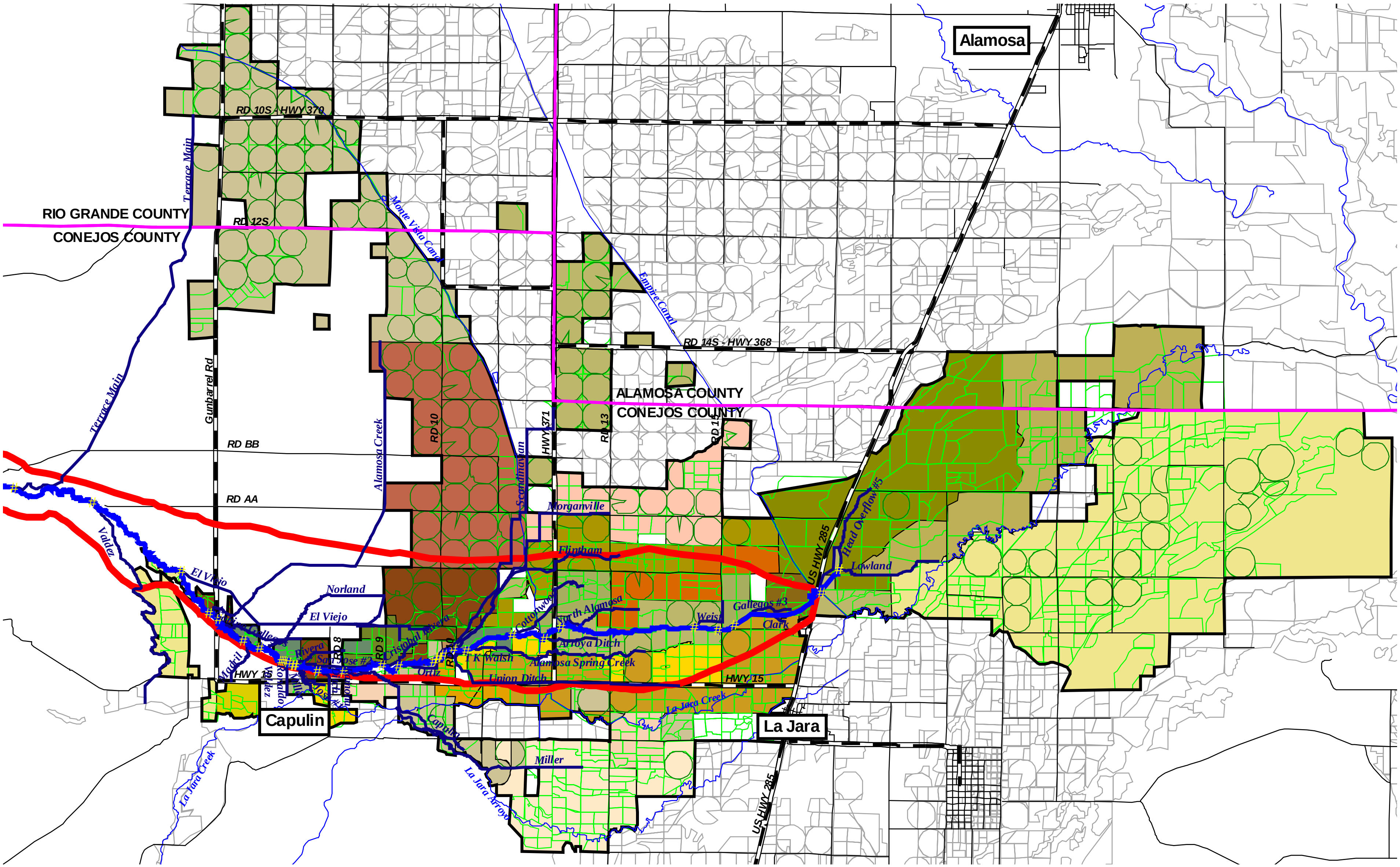
Table 2-28. Acreages Irrigated by Alamosa River by Crop

Crop	Acreage
Meadow Pasture and Grass Hay	22,679
Alfalfa Hay	18,077
Grain	11,459
Potatoes	983
Spinach / Lettuce	140
TOTAL	**53,338**

The shading in **Figure 2–104** indicates the service areas of different ditches that divert water from the Alamosa River watershed. The Terrace Main Canal serves the largest area irrigated primarily by the Alamosa River with 6,480 acres. The Terrace Main Canal has both direct flow rights as well as storage rights in Terrace Reservoir. Several documents have erroneously stated that Terrace Reservoir and the Terrace Main Canal provide water for 45,000 acres. The service area of the Empire Canal–Alamosa does encompass a larger overall area, but water is diverted from the Rio Grande, La Jara Creek, and the Alamosa River. The next largest ditch service areas are the Head Overflow #5, Alamosa Creek Canal, Lowland Ditch, and the Union Ditch. The majority of sprinklers are within the service areas of the Terrace Main and Alamosa Creek Canals.

2.11.2 Water Availability and Irrigation Diversions

A number of ditches divert water from the Alamosa River. The Alamosa River currently supports 36 ditches with rights to divert water through 34 headgates. Ditch water rights and water usage were also discussed in Section 2.3. However, additional analysis is appropriate to examine average ditch diversion, irrigation sufficiency, and adequacy of diversion structures. **Table 2-29** details water rights and diversion information for existing ditch headgates. Many ditches have several priorities, and the first priority number, number of priorities, and the total of ditch water rights are shown. Ditch water rights are expressed as a flow rate in cubic feet per second (cfs).



Alamosa River Watershed Restoration Master Plan

MWH in association with Agro Engineering, Lidstone and Associates, and SWCA

Figure 2-104. Diversions and Irrigated Areas

Note: Shadings represent service areas of different ditches; ditch names are noted on canal lines; many service areas overlap and some portions are not visible.

Average diversions were calculated using ditch diversion records between 1950 and 2002. Numerous ditch rights have been transferred from old locations into the existing ditch headgates, and historic diversion amounts were assigned to the current ditches. Ditch diversion amounts were summed and divided by the 53 year period of record to yield the average volume diverted per year. Years with no use were included in the calculation of the average using a flow of zero for those years. The number of years that the ditch was used and the average number of days used between 1950 and 2002 is also included. The average diversions in acre–feet were also converted to an average diverted flow rate over an approximate six month growing season. Both numbers can be used to examine the ditches with the largest and most reliable water rights. Ditches with an average 6–month diversion of at least 10cfs (3630 acre–feet) are indicated in bold. On average, the Terrace Main Canal is able to divert the highest volume on the Alamosa River. The Head Overflow #5 and Lowland Ditches, located at the end of the Alamosa River, divert the next highest amounts. The Terrace, Overflow, and Lowland Ditches have the largest total amount of water rights, but the majority of their rights are relatively junior. The El Viejo, Alamosa Creek, Valdez, and Capulin Ditches are able to divert the next highest volumes due to the seniority of their water rights.

Table 2-29 also lists the approximate amount of irrigated acres within the service areas of each ditch. Listed acreages were produced by the Rio Grande Decision Support System (RGDSS) irrigated lands assessment for year 1998 using satellite imagery, geographic information systems (GIS), and interviews with local representatives. The water supply from the Alamosa River was near normal in 1998. The average irrigation water supply provided by each ditch within its ditch service area was calculated as a depth in feet by dividing the average diversion between 1950 and 2002 by the irrigated acreage for the ditch. Alfalfa and grass hays require 28 inches of water or more in order to produce three full cuttings. Small grains require on the order of 16 to 18 inches. Ditch conveyance losses can be as high as 50% and application efficiencies range from approximately 50% for flood irrigation to 75% for sprinkler irrigation. Therefore, several feet of water is required to grow many hay and grain crops with a full water supply. Meadows and pasture often have smaller water supplies.

Many ditch service areas overlap and some parcels may receive water supplies from more than one ditch. However, many junior ditches from the Alamosa River do not typically have sufficient water for intensive crops throughout their entire service areas. Many irrigators in the Terrace ditch service area grow intensive crops with sprinklers, but supplement water from the Alamosa River with groundwater wells. Fewer groundwater wells have been drilled in other ditch service areas of the Alamosa River. Many smaller irrigators with junior rights often cannot raise intensive crops during drier years or rely on lower intensity crops such as meadows and pastures for livestock.

There are two volumetric storage rights for Terrace Reservoir that are not listed in the table (see **Appendix D**). Terrace Reservoir's number 11 priority is for only 44.75 acre–feet, while the second 17,171 acre–foot right is priority 110 and junior to almost all ditch rights. For this reason, Terrace Reservoir can only store water during the winter months when other ditches with more senior rights are not diverting water.

Table 2-29. Water Rights, Average Ditch Diversions and Water Sufficiency

ID	Ditch Name	First Prior.[1]	Water Right[2]	Irrigated Acres[3]	Years Used	Average Diversion[4] Days	Ac–ft	Ac–ft/ac	6 Month Avg. cfs
503	Alamosa Creek Canal	**1**	78.7	4898	52	163	**6460**	**1.32**	**17.8**
505	Alamosa Spring Creek	29	36.52	896	52	49	931	1.04	2.6
506	Arroya	36	53.12	1480	52	57	1813	1.22	5.0
510	Capulin Ditch	10	31.37	1479	53	131	4782	3.23	13.2
511	Clark	58	6.75	115	24	4	49	0.42	0.1
513	Cottonwood	44 (3)	35.7	522	51	35	636	1.22	1.8
514	Cristobal Rivera	15	7.08	789	53	78	874	1.11	2.4
520	El Viejo	1	14.4	1597	53	209	5079	3.18	14.0
522	Empire Canal–Alamosa	105	85	10985[5]	27	36	1776[6]	0.16[6]	4.9[6]
525	Flintham Ditch	45 (2)	27.125	1930	46	35	1101	0.57	3.0
526	Gabino Gallegos	11 (2)	35	901	53	100	2622	2.91	7.2
529	Gallegos 3	46	14.94	319	49	20	274	0.86	0.8
532	Garcia Ditch 2	13	5.54	797	53	74	496	0.62	1.4
539	Head Overflow #5	27(11)	155.725	5132	52	85	8366	1.63	23.0
550	La Hoya Ditch	92	3	No map	9	5	27		0.1
558	Lowland	57 (2)[7]	111.94[7]	4531[7]	52	93[7]	6856[7]	1.51[7]	18.9[7]
561	Miller–Alamosa	17 (4)	74.874	2639	46	46	1935	0.73	5.3
564	Morganville	73	20.75	2205	43	32	1146	0.52	3.2
570	Norland	68	48.56	968	45	31	859	0.89	2.4
571	North Alamosa	40 (3)	63.1	1608	50	42	1230	0.77	3.4
572	Ortiz	32	14.02	542	52	57	1141	2.11	3.1
581	Ramona	26	9.85	747	52	69	941	1.26	2.6
585	Rivera	88	28.8	306	24	10	124	0.41	0.3
586	Romaldo Valdez	24	2.37	53	52	63	334	6.31	0.9
591	San Jose Ditch No. 1	17	4.166	119	53	65	650	5.46	1.8
592	San Jose #2	14 (2)	16.58	60	52	55	137	2.28	0.4
593	Scandinavian Ditch	84	43.58	2284	36	20	923	0.40	2.5
600	T.K. Walsh	37 (2)	4.51	156	49	26	135	0.87	0.4
601	Terrace Main	2 (8)	142.02	6480	53	192	9712	1.50	26.8
602	Union	38 (3)	69.49	3619	51	52	2244	0.62	6.2
604	Valdez	9 (2)	71.63	662	54	167	3889	5.87	10.7
606	Weist	74	3.95	326	40	10	81	0.25	0.2
611	Madril	89	12.45	172	27	8	59	0.34	0.2
717	J.H. Valdez	–	5	2	2	0	2	1.25	0.0
3583	Terrace Reservoir	11 (2)	17215.75	6480	3	2	65	0.01	0.2

Notes: (1) If ditch has more than one priority, number of priorities listed in parentheses
(2) Total of Ditch Water Rights in cfs flow rate except Terrace Reservoir as ac–ft volume
(3) Irrigated acres in 1998 as determined by RGDSS Irrigated Lands Assessment
(4) Average Diversion between 1950 and 2002
(5) Includes acreage of Empire Canal – La Jara
(6) Portion of Empire Canal from Alamosa River estimated
(7) Includes Water Rights and Diversions from Overflow D1 N. Branch and S. Branch

Bold = Ditches with an average 6–month diversion of at least 10cfs (3630 acre–feet)

The ability for diversion structures to divert water from the Alamosa River has been impacted by deteriorated river conditions. Channel straightening increased velocities and bed shear stresses, and led to downcutting of the channel bed in many reaches. High rates of sediment deposition downstream of the erosional areas caused lateral instability and lateral erosion. Many headgates and check dams have had to be moved periodically in order to maintain access to diversion. Many irrigators on the Alamosa River have a difficult time affording repairs and changes to ditch headgates, and many irrigation structures in the river have been replaced using marginal materials and methods. Dam structures can also increase deposition in front of the dam increasing lateral erosion. **Figure 2–105** and **Figure 2–106** show examples of headgate problems. Photos of other headgates are included in the photo inventory available in an electronic appendix.

Figure 2–105. Poor River Condition– San Jose Ditch No. 1

Figure 2–106. Dam Constructed of Marginal Materials – Cristobal Rivera Ditch

Photo courtesy of Alan Miller.

Operations of Terrace Reservoir and water diversion patterns have a significant effect on the Alamosa River. The Terrace dam gates are closed for much of the winter and the river channel below Terrace Reservoir is dry. The six most senior water rights divert from the Alamosa Creek, El Viejo, Terrace Main, and Valdez Ditch headgates that are located upstream of the Gunbarrel Road. During lower river flows in late summer and fall, these senior ditches can use all the water available from the river. Therefore, the river channel below Gunbarrel Road is often dry for a majority of the year.

Lack of a constant instream flow significantly impacts local groundwater tables as well as riparian vegetation and trees. The lack of healthy riparian vegetation impacts bank stability and, in turn, the stability of diversion structures. Lower groundwater levels affect the ability to deliver water, especially to more junior ditches, as a significant portion of the flow may infiltrate into the channel bed. Regional groundwater levels have been significantly impacted by recent drought conditions. In 2002, small amounts of water were released from Terrace Reservoir for senior water users, but the water infiltrated before it reached farm areas for irrigation. Steve Vandiver with the CDWR has mentioned that at least 10 cfs is needed to get water to Capulin (see **Section 2.3**). This water may be needed to fill the void space caused by several months of dry channel. However, a constant instream flow may eventually build up local groundwater tables to the point where less base water is needed to maintain flows in the river.

The upper Alamosa River watershed naturally produces a high volume of sediments. Prior to construction of Terrace Reservoir, the lower Alamosa River was probably in a state of equilibrium with higher sediment loads. However, sediment loading may have increased due to historical mining and SCMCI activities at Summitville. Sediments are now deposited in Terrace Reservoir and, during most years, Terrace Reservoir has protected the lower Alamosa from the high loads of metal contaminated sediments. The gates of Terrace Reservoir have been plagued with problems, and the reservoir has been drained periodically throughout its history for repairs (see **Section 2.6**). When Terrace Reservoir is drained, large amounts of sediments have been flushed downstream into the lower Alamosa River. The effects of these sediment releases, at least in 1971 and 2004, have been severe.

After the sediment release in 2004, downstream irrigators had to divert water into several ditches in order to provide a flushing flow, and sediments initially blocked and plugged headgates and ditches. **Figure 2–107** shows the level of suspended sediments that were flushed into the Head Overflow Ditch at the end of the Alamosa River. Horses and cattle would not drink the water in the ditches. Several inches of sediment were deposited on meadows and pastures. Reportedly, the sediment is not productive and may have adversely impacted these meadows and pastures. Downstream irrigators paid the costs for excavation and repairs of ditches and headgates. Measures must be taken to control this sediment during future draining and maintenance of Terrace Reservoir.

Figure 2–107. Photo of Terrace Sediments Flushed into Head Overflow #5 Ditch

2.11.3 Agricultural Impacts Due to Water Quality

For thousands if not millions of years the Alamosa River watershed produced waters that were naturally acidic during many times of the year. However, open pit mining at the Summitville site severely impacted water quality in the lower Alamosa River watershed to degrees far beyond natural conditions. Water quality below Terrace Reservoir was examined in depth in **Section 2.4**. Shortly after SCMCI declared bankruptcy in 1992 water pH below Terrace Reservoir dropped below 5, and concentrations of copper, zinc, iron, and manganese reached levels as high as 1,500 μg/l, 400 μg/l, 5,000 μg/l, and 1,000 μg/l, respectively, Water quality has varied seasonally below Terrace Reservoir with lowest pH and highest metals concentrations often occurring during the irrigation season between July and September. Alamosa River irrigators diverted this water into ditches and irrigation ponds, and had to use this degraded water to irrigate their crops and provide water for livestock. The deteriorated water quality had impacts on agricultural infrastructure, soils, crops, and livestock. Water quality has improved considerably in the lower Alamosa River due to remediation efforts at Summitville. However, Summitville contamination deposited in Terrace Reservoir sediments may still be impacting downstream water quality.

Impacts on Infrastructure

The low pH in water diverted from the Alamosa River following SCMCI activities at Summitville had the potential to impact irrigation infrastructure built of steel or iron. Many headgates are built of steel, ditches run through a network of steel culverts, and many irrigators use center pivot sprinklers with steel piping and support structures. Numerous Alamosa River irrigators reported increased damage and wear to culverts, headgates, and sprinklers. **Figure 2–108** shows a photo of a culvert that was installed in 1994 and had to be removed within one year after being exposed to Alamosa River water. The extent of damage to irrigation infrastructure attributable to SCMCI activities at Summitville has not been documented and is difficult to quantify. A study by Cardon et al. (1995) did not find a statistically significant relationship to indicate increased damage to headgates. The most widespread damage was probably to culverts that were exposed to ditch water for extended periods. However, damage to sprinkler systems may have been more economically significant as sprinklers can cost $30,000 or more.

Figure 2–108. Photo of damage to culvert after exposure to Alamosa River Water

Impacts on Soils

Soils generally have an acid buffering capacity, but they are progressively changed by increasing acid inputs. A cooperative study by Colorado State University (CSU), the Colorado School of Mines (CSM), and Agro Engineering (Cardon and Kelly 1998) examined the impact of irrigation with Alamosa River water on soils and their acid buffering capacity.

Soils in arid regions typically contain calcite ($CaCO_3$), which readily neutralizes acid while soil pH remains high. Generally, soils in the San Luis Valley are naturally alkaline and contain a relatively high amount of calcite. Once the calcite is dissolved and removed from the soil, pH will decrease to a new level. Additional acidity will then be adsorbed by cation exchange sites primarily on clay particles and organic materials. Soils in the San Luis Valley have low amounts of organic materials, and cation exchange capacity (CEC) is dependent on the amount and type of clays. If the CEC is exhausted, the pH will again decrease and additional acid will be buffered by aluminum hydroxide minerals and then iron hydroxide minerals.

In the Cardon and Kelly (1998) study, samples of Greypoint type soil (the major soil type in the basin) were examined from several sites. Sites included a field that had been flood irrigated with Alamosa River water, a field that had been irrigated by Alamosa River water prior to open–pit operations at Summitville but was abandoned in 1984 (pre–84 site), a field that had never been farmed or disturbed (virgin site), and fields that had been flood irrigated by Rio Grande water.

Soil pH averaged 7.4 for the virgin site, 7.3 for the Rio Grande irrigated site, 6.4 for the pre–84 Alamosa River irrigated site, and 5.8 for the Alamosa River irrigated site. In the top meter of soil, the virgin site had a total of 41.44 $g/cm^2/m$ of calcite and the Rio Grande irrigated site had 298.16 $g/cm^2/m$ of calcite. On the other hand, the Alamosa River irrigated site had no observable calcite throughout the entire soil profile and the pre–84 Alamosa River irrigated site only had 4.51 $g/cm^2/m$ calcite. Agricultural soil samples taken for fields that are heavily irrigated with Alamosa River water commonly have no remaining calcite (Examination of soil sample data, Agro Engineering 2004).

The highest levels of both total and extractable copper and zinc were found in the Alamosa River irrigated site. Concentrations of total copper were 68.3, 48.6, 22.1, and 25.0 mg/kg at the Alamosa River site, Pre–84 site, Rio Grande irrigated sites, and the virgin site, respectively. Total zinc concentrations were 97.1, 77.7, 76.8, and 66.8 in these same sites, respectively. Examination of a large number of additional soil samples by Agro Engineering showed a consistent trend of lower pH and higher metal content related directly to the amount of Alamosa River water received by the soil. Fields with high priority water rights that received Alamosa River water after 1984 had the lowest pH and highest metals contents.

Clay contents in the top meter were 15.42, 7.28, 10.62, and 6.35 $g/cm^2/m$ at the Alamosa River site, Pre–84 site, Rio Grande irrigated sites, and the virgin site, respectively. The increase in clay in Alamosa River irrigated soils could be due to deposition of clay from sediment eroded from the Alamosa River watershed and depositing with flood irrigation, or from increased mineral weathering rates. Corresponding to the increased clay fractions, the CEC of the Alamosa River irrigated site was higher than the virgin and Rio Grande irrigated sites. However, on a CEC per unit mass of clay basis, the Alamosa River site had the lowest effective CEC per gram of clay (0.41 meq) while the Rio Grande irrigated site had the highest effective CEC per gram of clay (0.69 meq). This indicated an increase in the amounts of kaolinite in the clay fraction of the Alamosa River irrigated soil and a lower buffering capacity per unit mass of clay. Increases in kaolinite are consistent with acidic, high leaching weathering environments. The soil samples were examined using thin section analysis. For most samples, volcanic rock fragments dominated the soil composition with some amount of clay skins and iron oxide staining. On the other hand, the Alamosa River irrigated soil was aggressively weathered to the point that volcanic rock fragments were altered beyond identification, and iron oxides and clay minerals permeated the fragments.

Batch tests were performed to examine the buffer capacity remaining in the soils. The Alamosa River irrigated soils did not have the ability to buffer water back to neutral levels as no calcite remained in the soils. However, the buffering capacity was not exhausted as cation exchange related to clays continued to buffer acids. Actually, the total overall buffer capacity was higher in the flood irrigated Alamosa River soil than in the other soils as the soil had a higher content of clay. The level of pH remained buffered to about 6.0 until all silicates were dissolved from the soil, and significant metals were not released at this level.

It is predicted that the higher amounts of metals contained in the Alamosa soils may be released back into the water if soil pH dropped to 5. If this were to occur, the released metals would probably be toxic to crops and vegetation. The batch tests predicted that the soil would reach a pH of 5 in 300 years or more if the soil was regularly irrigated with pH 3 water. The tests predicted the soil would reach a pH of 5 in somewhere between 50 and 100,000 years if regularly irrigated with pH 4 water. Irrigation waters were observed below 5 shortly after SCMCI operations, but have generally been above pH 5 and are now typically above pH 6.

Therefore, Alamosa River irrigated soils have been affected by acidic waters from the watershed and particularly by the highly acidic waters produced by activities at Summitville. Metals contents are higher, calcite has been stripped from the soils, and the pH of some soils has been observed below 6.0. However, high clay contents in the soils provides an extensive buffer capacity and the pH of the soil will likely remain near 6.0 and should not reach levels that may release the metals back to soil water at toxic levels.

Impacts to Crops

Following SCMCI activities at Summitville, irrigators were forced to use water with high metal concentrations. There was concern that high concentrations of copper and manganese, in particular, may have impacted crops grown with the Alamosa River water.

Erdman et al. (1996) examined the potential impacts of degraded water quality on alfalfa irrigated with Alamosa River water. Alfalfa from three fields irrigated with water from Terrace Reservoir was analyzed for metal content and compared to alfalfa from three control fields irrigated with water from the Rio Grande and groundwater. The water from Terrace Reservoir that was being used for irrigation had significantly higher levels of both copper and manganese and lower pH than the other water sources.

Levels of manganese in the alfalfa irrigated by Alamosa River water were significantly higher than in alfalfa irrigated by the other water sources and exceeded levels commonly found in alfalfa from other areas. However, these levels were still well below the maximum tolerable level of manganese for cattle and sheep. Levels of cobalt were also higher in alfalfa grown with Alamosa River water. Levels of copper in the alfalfa irrigated by Alamosa River water were slightly higher than alfalfa irrigated by other water sources. On the other hand, the copper levels that were observed were actually near optimum nutritional levels for dairy cows and within levels found in alfalfa from other areas. However, maximum observed levels did approach the lower limit that is deemed harmful to sheep which are much less tolerant of copper than are cattle.

Therefore, the study indicated that the effects of Alamosa River water on alfalfa were noticeable, but levels were not observed that approached detrimental levels. Under a possible worse–case scenario that could have possibly existed in the watershed, alfalfa may have approached levels that could have been harmful to sheep.

Stout and Emerick (1995) examined uptake of metal in the heads of Moravian barley irrigated with water from the Alamosa River. Moravian barley is the variety commonly grown in the valley for the Coors brewery. During the summer of 1993, barley from three fields irrigated with water from Terrace Reservoir and three fields irrigated with water from the Rio Grande and groundwater were sampled for metals content. The barley irrigated with Alamosa River water did have higher concentrations of copper, zinc, potassium, nickel and barium that were statistically significant. However, differences were relatively small, and all metals concentrations were within reported ranges for metals in barley. The study did not note any observed impacts to the barley plants grown with Terrace water.

Cardon et al. (1995b) examined metal concentrations in the tissue of wheat and potato crops grown with water from the Alamosa River. Samples of wheat were taken from four fields grown with Alamosa River water and four fields grown with Rio Grande water. Potato samples were taken from one field irrigated with Alamosa River water and three fields irrigated with Rio Grande water. The study found no statistical differences in the metals content of wheat or potato tissues grown with the two different water sources. The study found that metals differences were more related to the soil than to the irrigation water. These soil differences could potentially be related to historical irrigation water sources

Impacts to Livestock

Livestock are an important part of the agricultural economy in the Alamosa River watershed. There has been concern that the ingestion of Alamosa River water and of forage irrigated with Alamosa River water may cause health effects in livestock. As part of the Risk Assessment for the Summitville site, Ramsdell (1998) investigated the potential impacts of metal contamination from the Alamosa River to domestic sheep.

Sheep are economically important to the agricultural communities in the Alamosa River watershed, and were selected for the study as they are known to be sensitive to elevated levels of copper. When sheep ingest elevated levels of copper, the metal is adsorbed by the liver and is bound in a relatively un–reactive form inside liver cells. However, with continued exposure, copper accumulates in the liver until the capacity of storing the copper in an un–reactive form is exceeded. Then, additional copper begins to damage liver cells and copper is released into the blood. The copper damages red blood cells and can then result in hemolytic anemia, kidney damage, and death of the animal. Sub–lethal effects of chronic copper toxicity include liver and kidney damage and may include neurological, immuniological, and reproductive damage (Ramsdell 1998).

During the summer of 1995, two groups of lambs were raised at a control site receiving water from the Rio Grande and at a ranch receiving water from the Alamosa River. The exposure site was thought to approximate a "worst–case" exposure. The sheep were penned within a grazing area irrigated exclusively by Alamosa River water with a ditch with Alamosa River water for drinking. The lambs were grazed at these sites for four months. During this time, blood samples were periodically drawn. After four months, the sheep were euthanized and liver and other tissues were examined.

None of the results indicated acute health effects in the exposed sheep. There were no toxicity related mortalities at the exposure site, there were no significant weight gain differences between the two sites, no gross lesions consistent with copper toxicity were observed, and no copper was detected in blood, muscle, or kidney tissues. However, copper concentrations in wool were higher in the exposed sheep. The exposed sheep had slightly higher levels of the liver enzymes acid phosphatase (AcP), aspartate aminotransferase (AST), and the liver protein metallothionein (MT). These changes were consistent with liver damage associated with accumulation of copper. In addition, levels of copper in the livers of sheep at the exposure site were about twice that as sheep in the control group. The liver copper levels were not high enough to indicate acute copper poisoning. The highest observed levels of copper in liver tissue were approximately half of that associated with copper toxicity that precedes sheep mortality. As copper was not detected in muscle tissue, it was not expected that humans would get unsafe amounts of copper from eating lamb meat.

If exposure had continued, further accumulation of copper was expected in the lambs. Ewes are grazed for several years and would be exposed for a longer time to potential contaminants. Therefore, an additional study was performed to examine copper toxicity in ewes that grazed in ranches in the Alamosa River watershed for several years (Ramsdell and Zylstra 1999). The study collected blood, wool, and liver biopsy samples over one year from ewes raised at 4 ranches where forage was irrigated by Alamosa River water (exposure sites) and at 2 ranches that received water from the Rio Grande (control sites). The concentration of copper in the ewes' livers, wool, or blood was not significantly higher in the sheep from the exposure sites than sheep from the control sites. Liver copper concentrations generally remained at levels less than half the level of copper toxicity. Liver copper concentrations did increase in ewes throughout the study period, but copper accumulation was not expected to lead to copper toxicity over the typical life span of a ewe.

Conclusions were not made about reasons for the differences in results between the two studies. However, the site for the first study was considered a "worst case" scenario, while the sites for the second study were typical ranch sites and copper levels in forage may have differed throughout the sheep range and the year. The lambs in the first study had to drink water from the Alamosa River for the entire study period. Ewes in the second study may have had a variety of drinking water sources including groundwater. Sheep are considered quite sensitive to copper levels in drinking water.

Therefore, it appears that sheep grazed in typical ranches in the Alamosa River may not be significantly impacted by higher copper levels and have probably not had significant adverse health effects. The potential exists that sheep grazed in a "worst–case" scenario similar to the site in the first sheep study may have accumulated higher concentrations of copper in their livers, especially during years of highest copper concentrations such as the years following open pit mining at Summitville. However, adverse health affects in sheep in the community have not been documented and a high prevalence is not expected. As sheep are much more sensitive to copper than cattle, potential impacts to cattle appears less likely.

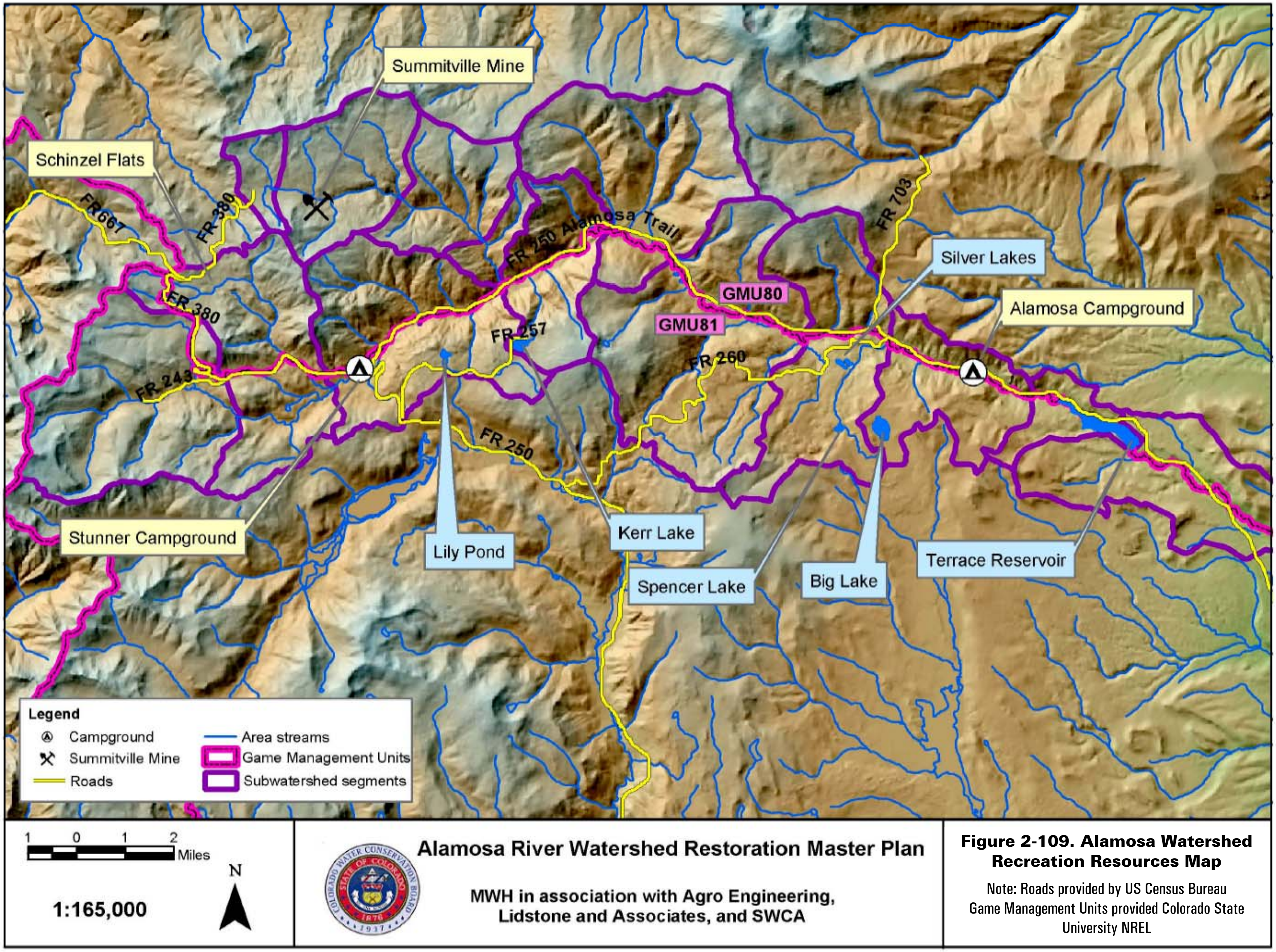
2.11.4 Key Agricultural Issues

The following bullets summarize major agricultural issues related to the Alamosa River:

- High rates of channel erosion and deposition impact headgates and water diversion.
- Operation of Terrace Reservoir and senior ditches creates a dry channel for much of the year.
- A dry channel impacts the stability of diversion structures and the delivery of water due to lowered local groundwater levels and reduced riparian vegetation.
- Release of sediments during the draining of Terrace Reservoir impacts diversions and agricultural lands and places a burden on downstream water users.
- Degraded water quality impacted irrigation infrastructure, agricultural soils, crops, and livestock.

2.12 Recreational Uses

The Alamosa River watershed has a long history of recreational uses. Within the watershed, recreational opportunities are available on USFS lands, BLM lands, state wildlife areas, Terrace Reservoir, privately owned campgrounds, University Science Camp, and a youth ranch offering wilderness experiences to teenagers. For more than a century, the river system has supported many different forms of recreational uses. The majority of available recreational opportunities that exist in the Alamosa River watershed come from the Rio Grande National Forest (RGNF), partly because the bulk of the watershed is within the forest. The RGNF participated in the National Visitor Use Monitoring project from January 1 through December 31, 2000 and concluded that there were approximately 1.3 million visitors to the RGNF that year (USDA 2001). This visitor estimate is based on the visitor survey data obtained for the entire forest. Results from the survey indicate that these visits were primarily to developed sites, general forest areas, and wilderness areas, or associated with permitted services. The USFS identified the top recreational activities as viewing scenery, wildlife viewing, driving for pleasure, hiking, and bicycling. The next formal visitor use survey is planned for fiscal year 2004 (USDA 2002).



Alamosa River Watershed Restoration Master Plan

MWH in association with Agro Engineering, Lidstone and Associates, and SWCA

Figure 2-109. Alamosa Watershed Recreation Resources Map

Note: Roads provided by US Census Bureau
Game Management Units provided Colorado State University NREL

Historically, the most popular recreational opportunities in the Alamosa River watershed include fishing, swimming, wildlife viewing, camping, hiking, horseback riding, recreational touring, hunting, and off–highway vehicle (OHV) use. Winter recreation activities within the watershed may include cross–country skiing and snowmobiling. Current recreational utilization in the watershed is believed to be lower than historic utilization. Water quality degradation and human–induced environmental conditions in the early 1990s diminished fisheries populations in the watershed. The lack of a fishery limits the recreational opportunities in the watershed (Conejos County Soil Conservation District [CCSCD] 1997). In addition, water quality conditions in the early 1990s, and the public reaction to fish kills and a seemingly "dead" river, impacted the visitor utilization of the area. However, the scenic value of the surrounding San Juan Mountains continues to bring visitors to the watershed. Since the EPA assumed control of the Summitville Mine and began to treat runoff from the site, the water quality in the river and adjacent tributaries has improved. As a result, the native fishery populations are slowly beginning to return, which is expected to increase recreational utilization of the area. However, the deterioration of the river channel, water quality, and water availability are still limiting factors in the level of recreational opportunity utilization.

For the purposes of describing the current recreational utilization, the watershed was divided into three parts. The delineation of these subwatersheds was based on current environmental conditions, disturbance from human activities, and geography. The following three parts of the watershed were delineated: (1) the uppermost portion of the watershed not affected by the Summitville Mine, upstream from the confluence of the Alamosa River and Wightman Fork (subwatersheds 10 through 12 and T1); (2) the confluence of the Alamosa River with Wightman Fork downstream to Terrace Reservoir (subwatersheds 5 through 10, W1 through W4); and (3) from the spillway at Terrace Reservoir downstream to U.S. Highway 285 (subwatersheds 1 through 4).

Upper Watershed above Wightman Fork

Many recreational opportunities exist in this upper portion of the watershed. Stream reaches in this watershed segment include: Prospect Creek, Treasure Creek, Cascade Creek, Gold Creek, Iron Creek, Globe Creek, Alum Creek, Bitter Creek, and Asiatic Creek. The USFS currently operates the Stunner Campground located 1 mile west of the intersection of Forest Road (FR) 250 and FR 380. The USFS does not maintain records of visitation at this non–fee, developed site because the water quality in the river limits recreational activities (CCSCD 1997). This developed campground offers ten camping sites with a vaulted lavatory. The campsite is situated near the historic mining town of Stunner, an 1892 gold fever camp at an elevation of approximately 9,700 feet. The river flows just below the site and allows for limited fishing for brook and other species of trout. Two undeveloped campgrounds are located along the four–wheel drive (4WD) FR 257 providing OHV recreation, scenic views, camping, fishing, and wildlife viewing opportunities. FR 257 passes Lily Pond and continues east to Kerr Lake. Fishing opportunities are considered excellent at Kerr Lake; however, winter fish kills occasionally happen at Lily Pond. No visitation records are available for these undeveloped campgrounds.

FRs 250, 380, and 243 provide access to visitors wishing to view the continental divide and to access the many small tributaries known to support fish populations. Other lesser–known trails in this segment may provide recreational opportunities and visitor access in the form of hiking, OHV use, horseback riding, and bicycling. Accessing the Schinzel Flats area via Soldiers Road provides visitors an opportunity to see alpine bogs, wildflowers, typical alpine wildlife, and views of the Continental Divide from Elwood Pass.

This portion of the watershed is located in Big Game Management Units 80 and 81. Management Unit 80 is located north of FR 250 and the main river stem, and generally includes the watershed north of the river. Management Unit 81 is located to the south of FR 250 and the main river stem, and generally includes those watersheds south of the river. According to CDOW records, two of the most popular game species for hunters in these management units are mule deer and elk. CDOW harvest records for these species of big game indicate a 2003 deer harvest for both units of 249 bucks. A total of 537 deer hunters utilized these units. Total recreation utilization by deer hunters was 2,732 recreation days in both units (CDOW 2004a). Elk hunting is, by far, the most popular big game species for hunters. Hunter use records indicate a 2003 harvest of 1,962 elk, which includes bulls, cows, and calves. This equates to 11,715 hunters utilizing these units for recreational elk hunting in 2003. Total recreational days for units 80 and 81 are 29,471 and 30,954, respectively (CDOW 2004a). Harvest statistics for other game species can be accessed on the Internet at http://wildlife.state.co.us/huntrecap/.

Most recreational opportunities in this segment occur from Memorial Day to Labor Day, prior to the winter season. Winter recreational activities in this portion of the watershed are limited due to heavy winter snow and road closures.

Prior to mining in the late nineteenth and twentieth centuries, documentation of fisheries in the upper Alamosa River watershed indicated that naturally occurring metal concentrations did not prohibit colonization of the river and associated tributaries (Woodling 1995). CDOW stocked fingerling Snake River cutthroat trout in Prospect and Treasure Creeks in 1992 and 1993, but natural water quality may limit the productivity of the uppermost reaches of these creeks (Woodling 1995). Upstream of the Schinzel Flats area, gradient and lack of suitable habitat, not metal concentrations in the water, prohibit a fishery in Iron Creek (Martin 1994). Trout populations have been documented in Iron Creek below Schinzel Flats, allowing for limited fishing opportunities. A naturally reproducing population of brook trout was documented downstream of Gold Creek to just upstream of Alum Creek (Martin 1994; Woodling 1993). Angler reports for several years also have reported brook trout in Gold, Cascade, and Asiatic Creeks. These have historically been viable fish populations since the CDOW has never stocked these stream reaches (Woodling 1995). Alum and Bitter Creeks drain portions of the same hydrothermal alteration area as Wightman Fork. With Wightman Fork, these creeks introduce acutely toxic concentrations of heavy metals into the river (more information on water quality is available in **Section 2.4**). Studies indicate that no fish populations exist in these creeks due to a combination of acidity, metal concentrations, steep gradient, and lack of deep–water areas for fish to overwinter (Woodling 1995). Regardless of water quality, the lack of suitable habitat in Alum and Bitter Creeks limits fish populations. Brook trout and other fish species were known to exist in the Wightman Fork drainage area prior to the development of water quality problems in the late 1980s. Since then, water quality below Summitville, and lack of suitable habitat upstream of the mine, limits fishing opportunities in Wightman Fork.

The presence of viable fish populations in the upper watershed correlates to the amount of recreational utilization of the area (CCSCD 1997). Anglers and other recreationalists utilize those stream reaches known to support fisheries. The absence of fisheries in other portions of the upper watershed limits recreational utilization.

2.12.1 Middle Watershed, Wightman Fork to Terrace Reservoir

This portion of the watershed includes Jasper, Burnt, Spring, Fern, Silver, Lieutenant, Ranger, French, and Beaver Creeks. Silver Lakes, Spencer Lake, Big Lake, and several gulches also are present in the middle section of the watershed. The USFS currently operates one undeveloped campground within this segment. Located at an elevation of 8,700 feet, the Alamosa Campground is situated along the Alamosa River, nestled among spruce and other conifers. The campground has a capacity of ten sites with vault toilets. The campground is convenient to Terrace Reservoir, the Alamosa Trail, and several off–road trails. The USFS does not keep visitation records for this non–fee campground.

A private youth ranch and a university science camp are located within this section of the watershed. The youth ranch offers recreational opportunities such as pack animal excursions, horseback riding, hiking, backpacking, rock climbing, fishing, and environmental appreciation for teenage youth. The science camp offers students eco–tours of the region with various camping, fishing, and wildlife viewing opportunities.

The Alamosa Trail runs concurrently with the scenic drive FR 250. This trail offers recreational uses such as pleasure driving, hiking, bicycling, and other trail related activities. In addition to recreational opportunities, FR 250 serves as a gateway from the east into the middle and upper watershed. The road serves as the primary access for year–round and seasonal residents of the Jasper community. Another road in this segment is the maintained 4WD FR 260, which allows travel between FR 250 and Platoro. Other notable trails in this watershed segment are the Big Lake trail, offering cross–country skiing in the winter and waterfowl observation, and the Silver Lakes trail (FR 260). Big Lake is subject to winterkill and generally is too shallow to support a viable fish population. Several other lesser known trails and roads, such as the Silver Mountain trail and Alamosa Rock Creek Trail 703, provide additional recreational opportunities and visitor accessibility.

Terrace Reservoir is located at the lower end of this watershed section and is privately owned by the Terrace Reservoir and Irrigation Company. The reservoir is drawn down annually to supply water to meet the irrigation demands in the valley. The CDOW, in agreement with the Terrace Reservoir Irrigation Company, maintains a conservation pool of 67 surface acres.

Rainbow trout were stocked in Terrace Reservoir by the CDOW between 1960 and 1990. In the 1980s, angler catch rate was approximately 0.5 fish per hour with an average length of 10 inches (CDOW 2003). In 1990, heavy metal laden water resulted in a complete fish kill at the reservoir. In 1990, the CDOW suspended all stocking activities in the reservoir and along various stream segments of the river until mine cleanup activities and surface water quality allowed for the recovery and survival of stocked trout.

In 2000, CDPHE confirmed that water quality conditions had improved to a point allowing for the survival of stocked trout populations. The following year, the CDOW stocked 7,003 subcatchable rainbow trout in the reservoir (CDOW 2003). A standard gillnet inventory was completed in the Fall 2001. The inventory indicated the presence of Snake River cutthroat trout, Rio Grande cutthroat trout, Rio Grande chub, and rainbow trout in the reservoir. The presence of unstocked fish species in the reservoir indicated the potential for existing upstream fisheries in the watershed (CDOW 2003). The inventory showed that some species of trout can survive in the reservoir. However, CDPHE currently has signs posted at the reservoir that fish in the reservoir are part of a scientific study and should not be consumed. Water quality and availability in the watershed continue to be the limiting factor for the productivity of fishery populations and associated recreational prospects within the reservoir and along the main stem of the river.

Big Game Management Units 80 and 81 on BLM and USFS lands in this section offer hunting opportunities for many small and big game species of wildlife.

The Terrace Reservoir State Wildlife Area surrounds the reservoir and provides additional recreational activities on lands adjacent to the impoundment. The area offers a wide variety of big game hunting, including deer, elk, bear, mountain lion, and bighorn sheep. Small game hunting is available for cottontail rabbits and snowshoe hares, along with trapping for coyotes, bobcats, and martens (CDOW 2004b). Other recreational pastimes in the wildlife area may include wildlife viewing, primitive camping, and photography.

Winter activities in this portion of the watershed include cross–country skiing at Big Lake and snowmobiling along the many established USFS roads and trails. Road maintenance of FR 250 in the winter allows for visitor accessibility to this segment of the watershed.

2.12.2 Lower Watershed, Terrace Reservoir Downstream to the San Luis Valley

Below Terrace Reservoir, the lower portion of the watershed does not offer as many recreational opportunities when compared to the middle and upper portions of the watershed. This is partly due to the lack of public land in the lower watershed. Other factors affecting recreational opportunities include water quality, water availability, and lack of viable fisheries. Currently, water demands and allocations for agricultural use have lowered the water table in the valley, severely limiting the amount of surface water available in the Alamosa River. The lack of surface water in the river for parts of the year severely limits fishery productivity. Channel scouring and loss of native habitat further restricts the redevelopment of fisheries in the lower watershed. Historically, fisheries did exist in the valley. As early as 1891, scientific studies indicated four species of fish in the lower porti7on of the watershed (Woodling 1995). A 1984 study indicated reproducing populations of fathead minnows, carp, and white suckers near the crossing of U.S. Highway 285; however, recreational anglers do not typically target these species. Over the last 20 years, water quality, drought, water allocations, and stream morphology have likely depleted the fish populations in the valley and upstream to Terrace Reservoir. Other recreational opportunities in this portion of the watershed may include hunting and wildlife viewing.

2.12.3 Key Recreation Issues

Key recreation issues that should be addressed by the Master Plan include:

- Impaired fisheries and lack of water in the river downstream of Terrace Reservoir limit recreational use of the Alamosa River and tributaries.
- Water quality and availability in Terrace Reservoir may limit fishery productivity and recreational opportunities.
- Public perception of the Alamosa River watershed health deters recreational utilization.

2.13 Segment/Subwatershed Characterization

This section describes an overall evaluation of the Alamosa River watershed stream segments and subwatersheds, based on the detailed resource assessments in the previous sections. Evaluation criteria were developed for each of the main resource categories. Criteria definitions and the basis for qualitative scoring are presented in **Table 2-30**. Performance of each stream segment according to each criterion was rated on a qualitative good/fair/poor scale.

Table 2-30. Stream Segment and Subwatershed Evaluation Criteria

Resource Category	Criteria	Basis for Scoring
Channels	• Channel Stability • Channel Capacity	• Stability associated with Rosgen stream classification • Ability to convey normal flood flows without damage to channel and structures in floodplain
Surface Water Quantity	Natural Flow Regime	• Base flows and high flows approximating natural variability in similar watersheds
Surface Water Quality	• Beneficial Uses • Watershed Runoff Quality	• Supports designated uses in segment • Runoff and base flow water quality from watershed
Ground Water	Beneficial Uses	• Supports human uses (agricultural pumping) and natural functions (riparian habitat)
Terrace Reservoir	Design and Operation	• Physical structures and operating policies to support multiple benefits (water quantity, recreation, water quality, agriculture), sediment management during large releases
Sediments	• Channel Sediment Balance • Watershed Sediment Production	• Balance of sediment load (aggradation/degradation) in channel • Balance of sediment production from watershed
Riparian Habitat	Health and Diversity	• Health and diversity of vegetation and aquatic habitat in riparian corridor
Biological Resources	Health and Diversity	• Health and diversity of species (particularly T&E and sensitive species) and habitat in watershed
Agricultural Resources	Agricultural Benefits	• Effectiveness of diversions, availability of irrigation water, and suitability of water quality
Recreational Uses	Recreational Values	• Supports historical and potential recreational values (fishing, camping, boating, etc.)

Table 2-31 provides the qualitative ratings for each stream segment/subwatershed.

Table 2-31. Stream Segment and Subwatershed Rating

	Stream Segment/Subwatershed														
Category – Criterion	1	2	3	4	5	6	7	8	9	10	11	12	T1	W1–3	W4
Channels – Channel Stability	Poor	Poor	Poor	Fair	N/A	Fair	Good	Good	Good	Good	Good	Good	Good	Good	Good
Channels – Channel Capacity	Poor	Poor	Fair	Good	N/A	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Surface Water Quantity – Natural Flow Regime	Poor	Poor	Poor	Poor	N/A	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Surface Water Quality – Beneficial Uses	Fair	Fair	Fair	Fair	Fair	Poor	Poor	Poor	Poor	Poor	Fair	Fair	Good	Poor	Good
Surface Water Quality – Watershed Runoff Quality	Fair	Fair	Fair	Good	N/A	Good	Good	Good	Good	Good	Poor	Poor	Good	Poor	Fair
Ground Water – Beneficial Uses	Fair	Fair	Fair	Fair	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Terrace Reservoir – Design and Operation	N/A	N/A	N/A	N/A	Poor	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sediments – Channel Sediment Balance	Poor	Fair	Fair	Poor	N/A	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Sediments – Watershed Sediment Production	Good	Good	Good	Good	N/A	Good	Good	Good	Good	Fair	Poor	Poor	Fair	Fair	Fair
Riparian Habitat – Health and Diversity	Poor	Poor	Poor	Fair	N/A	Poor	Poor	Poor	Poor	Poor	Fair	Fair	Good	Poor	Good
Biological Resources – Health and Diversity	Poor	Poor	Poor	Fair	Poor	Poor	Poor	Poor	Poor	Poor	Good	Good	Good	Poor	Good
Agricultural Resources – Agricultural Benefits	Poor	Poor	Poor	Good	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Recreational Uses– Recreational Values	Poor	Poor	Poor	Fair	Poor	Fair	Fair	Fair	Fair	Fair	Fair	Good	Good	Poor	Good
N/A – not applicable	Co Rd 10 to Point of last diversion	Gunbarrel Rd to Co Rd 10	Terrace Main Canal to Gunbarrel	Terrace Main Canal to Terrace Outlet	Terrace Reservoir	French Creek to Terrace Reservoir Inlet	Beaver Creek to French Creek	Fern Creek to Beaver Creek	Jasper Creek to Fern Creek	Wightman Fork to Jasper Creek	Iron Creek to Wightman Fork	Treasure Creek to Iron Creek	Treasure Creek	Wightman Fork below Summitville	Wightman Fork above Summitville