2.3.7 Summary of Surface Water Quantity Issues

The key surface water quantity issues are:

- Highly altered hydrologic regime impairs natural functions and values.
- Historical streamflow has been significantly altered by water use for agriculture and other purposes, particularly by operation of Terrace Reservoir. The river is dry downstream of Terrace Reservoir during late fall, winter, and early spring.
- The Alamosa River is a highly over–appropriated stream.
- There are no unappropriated surface flows for environmental purposes.
- There may be limitations on future new storage, due to the Rio Grande Compact.

2.4 Surface Water Quality

2.4.1 Effects of Geology on Regional Water Quality

The water quality of the Alamosa River has been highly influenced by its unique geological setting. Information for the following discussion was drawn primarily from Neubert (2001) and Bove et al. (1995) that were produced through studies by the Colorado Geological Survey (CGS).

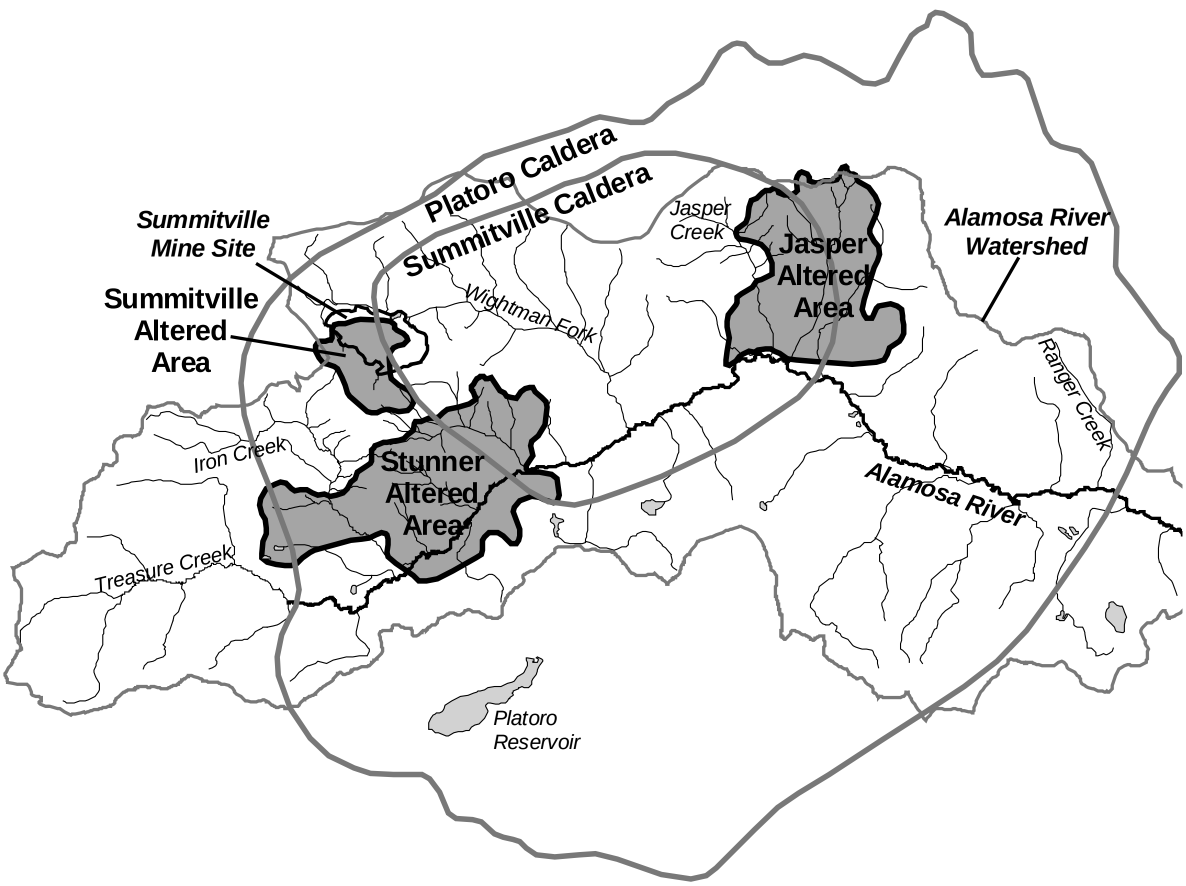
The geology of the upper Alamosa River is dominated by two ancient volcanic calderas in the San Juan Volcanic Field. The volcanic field began forming about 35 to 40 million years ago with the eruption of cone–shaped strato–volcanoes similar to Mount St. Helens. After extensive erosion of the strato–volcanoes, about 30 million years ago, a more explosive period of volcanism began that produced tremendous volumes of ash that were lighter in color due to high silica content. A huge magma chamber collapsed to form the Platoro Caldera which encompasses much of what is now the upper Alamosa River watershed. An additional eruption and subsequent magma chamber collapse formed the Summitville Caldera nested within the Platoro Caldera.

Continued large–scale volcanic activity caused extensive faulting that later served as conduits for mineralization. About 26 to 29 million years ago, molten rock intruded into the Jasper and Stunner areas, and magma intruded below the South Mountain dome and the Summitville area about 23 million years ago. The magma released large volumes of sulfur dioxide gas which rose along the fractures and faults. The gases condensed and produced sulfuric acid that extensively leached and altered the bedrock. Hydrothermal alteration continued as the magma produced hot fluids that deposited metal–sulfide minerals such as iron pyrite. Geysers and hot springs similar to those found in Yellowstone may have existed in some areas. The areas where this alteration occurred are often referred to "hydrothermally altered" or "altered" areas in the literature and subsequently in this text. Altered areas are quite apparent as the oxidation of primarily pyrite has formed deep colors of orange, red, and tan. These deep colors are apparent in the following photo of Lookout Mountain (**Figure 2–32**) from near Iron Creek in the Stunner altered area. **Figure 2–33** shows the location of the Jasper, Stunner, and Summitville altered areas within the Platoro and Summitville calderas and the Upper Alamosa River watershed.

Figure 2–32. Photo of Lookout Mountain in Stunner Altered Area

Modified from Bove et al. 1995

Figure 2–33. Hydrothermally Altered Areas in Alamosa River Watershed



The effects of eroding altered areas on water quality are significant. Where mineralized areas have been disturbed by mining, the effects on surface water quality are profound. Strongly pyritic rock has been extensively deposited throughout the altered areas. Iron pyrite and other sulfide minerals, when exposed to oxygenated rain or snowmelt, oxidize and generate sulfuric acid. This acid in turn dissolves metals contained in the rock. The dissolved metals and acid inhibit the formation of soil and vegetation, and the lack of protections increases rates of erosion. The release of sediments, acid and dissolved metals to surface waters can significantly impact water quality. Mining increases rock dis–aggregation and greatly increases the surface area of mineralized rock exposed to oxidation and contact with water. The Alamosa watershed contains areas with naturally high areas of weathering and erosion as well as areas that have been significantly impacted by mining activities.

Veins and lenses of potentially economic minerals were deposited in fractures within the altered, strongly pyritic rock. As the Summitville area was more mineralized than the other altered areas, acidic water produced in the Summitville area has a potential to dissolve higher concentrations of metals such as copper and zinc than in other areas.

The primary mineral foundation created by the acidic alteration was clay. Clay is easily eroded, and fine clay particles are easily suspended and contribute to high levels of suspended sediment in the Alamosa River. Suspended sediments appear to be a significant water quality problem in the Alamosa River particularly during spring runoff and after precipitation events.

2.4.2 The Summitville Legacy

Placer gold was first discovered in Wightman Fork during the summer of 1870. Between 1870 and 1992, mining took place at Summitville in 86 of the 123 years (Posey and Woodling 1998). Significant lode mining began by 1875, and by 1883, the Summitville district was the third largest gold producer in Colorado with nine mills. Production started to decrease by 1888 as oxidized ore in surface deposits was depleted and deeper mines had to be developed to mine the lower–grade sulfide ores. Gold was primarily produced at Summitville as well as some silver, but small amounts of copper and lead production were first recorded in 1896. The 2,500 foot Reynolds adit was completed in 1897 near the base of South Mountain as access for the underground workings and to drain the mines. Production was limited between 1906 and 1925, but was more significant between 1926 and 1949. Between 1949 and 1984, activities at Summitville were primarily limited to explorations including copper exploration in the late 1960s, gold and copper exploration by ASARCO in the late 1970s, and gold prospecting by Anaconda in the early 1980s. Prior to 1984, total production from Summitville was on the order of $7 million (Wood 2001).

In 1984, Summitville Consolidated Mining Company Inc. (SCMCI), a subsidiary of Galactic Resources Ltd., obtained a permit to operate a heap leach gold mining operation from the Colorado Mined Land Reclamation Board (MLRB). The MLRB and the Colorado Division of Minerals and Geology (DMG) are responsible for mine permits and operations under the Colorado Mined Land Reclamation Act of 1976.

Danielson and Alms (1995) details the list of mishaps that then ensued at the Summitville site, and much of the following information is drawn from that account. Construction of an upper geomembrane liner over a clay liner began at Summitville in the fall of 1985, and liner construction continued throughout the winter of 1985–86. During the winter construction, the liner froze, buckled, and cracked, and the winter construction led to liner rips, tears, and inadequately sealed seams. On June 5, 1986, SCMCI began leaching operations, and on June 11, cyanide was detected leaking through the geomembrane liner. However, the heap leach pad was loaded with a substantial amount of ore and operation continued. On

June 18, the lower clay liner was found to be leaking and cyanide solution was entering the French drain below the liner. In October, plans were approved to construct a sump downstream of the pad to intercept leaking cyanide solution and pump it back onto the heap leach pad. The DMG approved the plan based on limited baseline data from SCMCI that claimed that evaporation exceeded precipitation at the site. However, additional groundwater then entered the water balance, and the pumps and leaching operation now had to operate continuously. By June 1987, the pump system experienced repeated failures and at least 85,000 gallons of cyanide contaminated solution was released into Cropsy Creek. By 1988, it became obvious that water balance estimates were wrong and natural precipitation exceeded evaporation although a winter cover was never placed over the pad as specified in the mine permit. The accumulation rate in the heap doubled and water depth increased as well as leakage.

In May, 1989, the Water Quality Control Division (WQCD) approved a discharge permit for a water treatment plant to treat the accumulating water and discharge it to Wightman Fork. However, by June, it became apparent that the treatment plant was incapable of treating water to the extent required. SCMCI then obtained approval from the DMG to land apply the contaminated water. However, SCMCI failed to indicate to the DMG that a clay layer underlay the application site, and the application site area was reduced from the proposed 17 acres to 5 acres. In July 1990, WQCD inspectors discovered that the land application was causing overland flow of contaminated solution directly to Wightman Fork, although the WQCD did not act on the violation until February 1991. At this time, leakage from the Cropsy Waste pile was seeping into Cropsy Creek, and breakdowns of the pump back systems were causing additional untreated discharges. However, in December 1992, SCMCI declared bankruptcy with only 11 days notice. The company abandoned the water treatment plant and operations of the pump back system that were retaining millions of gallons of cyanide laden water at the start of one of the most severe winters in recent years.

Upon receiving the abandoned site, the State of Colorado realized the potential for significant environmental impacts and requested assistance from the EPA. The EPA assumed control of the site under emergency authority and battled to keep the heavily contaminated solutions from the heap leach pad from discharging to Wightman Fork. The site was listed on the National Priorities List in 1993 and became a Superfund site under CERCLA authority. Between 1984 and 1992, 259,000 troy ounces of gold were produced with an estimated value of $81 million (Wood 2001). To date, over $185 million has been spent by the state of Colorado and the US government to clean up the site (J. Hanley, EPA oral communication, 2004).

Blame for the Summitville disaster has been leveled on many entities. But regardless of who is to blame, the open pit operations have left a legacy in the Alamosa River watershed. Untreated discharges from the site caused significant decreases in pH, significant increases in dissolved metals, and releases of cyanide to Wightman Fork. Fish were killed in the Alamosa River below Wightman Fork, in Terrace Reservoir, below Terrace Reservoir, and in fish ponds supported by Alamosa River water. Highly acidic water impacted the agricultural infrastructure, crops, soils, and livestock of downstream water users.

2.4.3 Sources of Water Quality Contamination

Summitville

During vulcanization of the Alamosa River watershed area, magma was intruded below the South Mountain volcanic dome to about 2000 feet below the current surface and intensely altered the overlying materials. However, in comparison to the Jasper and Stunner altered areas, much less of the Summitville area was naturally eroded. The valley at the upper end of Wightman Fork is relatively shallow and slopes are not as steep as those draining other altered areas such as Alum or Burnt Creeks. Prior to historic mining, the Summitville area below timberline was mostly forested by coniferous trees.

Soils in the timbered areas probably included an organic horizon that limited erosion of altered materials. In addition, organic horizons in coniferous forests in the area typically have a large water holding capacity, and would have limited the infiltration of precipitation into the underling materials (Medine 1997). The most intensely altered "vuggy silica" zone at Summitville was naturally weathered and oxidized to a depth of about 300 feet. This oxidization removed sulfides and enriched minerals such as gold. Oxidation of the remaining altered area was limited to several tens of feet (Plumlee et al. 1995). Prior to mining, oxidation of additional area below the oxidized zones was limited by low permeability due to high clay content and clay layers in the altered zones, and groundwater tables with relatively low dissolved oxygen. Therefore, prior to mining, water quality impacts due to the Summitville altered area may have been significantly less than current natural impacts from the Stunner and Jasper altered areas.

Underground mining and installation of drainage tunnels such as the Reynolds and Chandler adits at Summitville significantly altered the hydrology of the site. Groundwater tables with relatively low dissolved oxygen were lowered and replaced with atmospheric oxygen and flushes of oxygenated water from precipitation. Tunnels and mine disturbances increased the contact area for oxygen and waters with the sulfide ore zone. Therefore, early mining at Summitville probably did significantly impact water quality in Wightman Fork and the Alamosa River compared to pre–mining conditions.

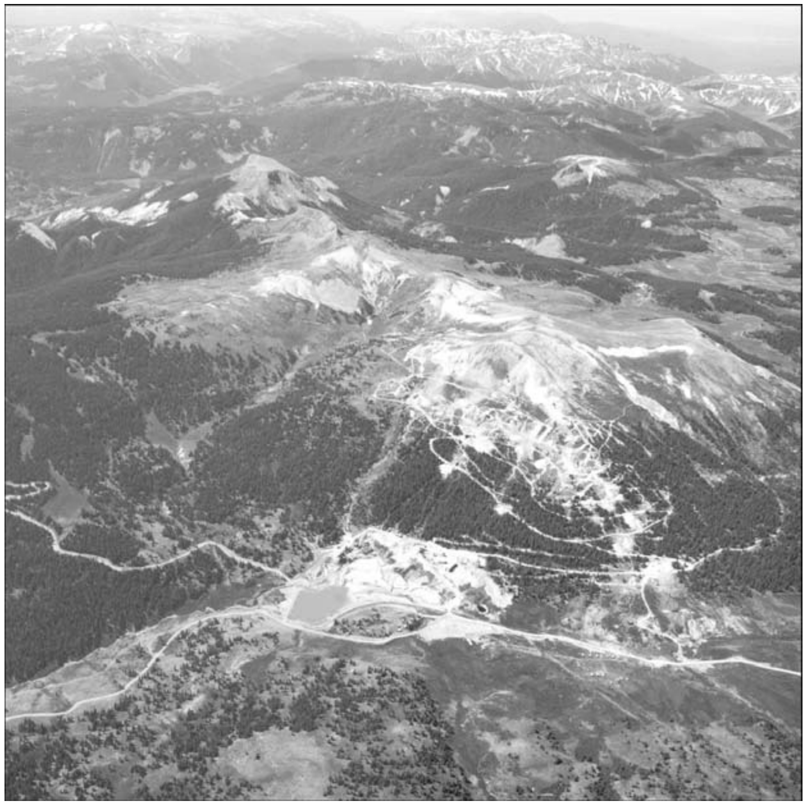
However, impacts due to open pit mining were orders of magnitude higher than impacts from earlier mining activities. Prior to the open pit and heap leach mining by SCMCI, almost all mine workings except the earliest placer prospects were underground. **Figure 2–34** shows a photo of Summitville in 1980 before the SCMCI mining operations. Even at that time, much of the Summitville site was still timbered. Several bog areas were also present below the site that may have retained runoff and likely attenuated metal concentrations.

Figure 2–35 shows Summitville in 1991 following a tremendous transformation of the site due to SCMCI operations. A large forested area was cleared for the heap leach pad, many internal areas were denuded as a result of roads and operational areas, and extensive excavation at the open pit and the headwall area exposed a large area of altered materials. Nearly the entire site was exposed to oxidization and erosion processes. Most ore was mined from the upper oxidized zone. Therefore, the area of un–oxidized sulfide minerals below the oxidized zone was exposed to weathering, oxidation, and acid–metal generation. Rock was excavated and crushed and mounded in dump piles and the heap leach pile. Over twenty million tons of rock were excavated from the open pit and made available to oxidation. Operations disturbed an area of 633 acres in addition to the 33 acres of previously disturbed area at the base.

The open mine pit created a catchment basin that funneled all snow and rain precipitation through sulfide–rich materials into mine workings and the Reynolds adit below the pit. Water quality from the Reynolds adit degraded significantly during SCMCI activities (see **Section 2.4.6**, **Figure 2–54**).

The Reynolds adit was plugged in 1994 and mine pits have since been filled and graded as a part of remedial efforts by CDPHE and the EPA. Revegetation of much of the Summitville site was completed in 2001. The vegetative cap is designed to stabilize slopes and separate uncontaminated surface runoff from precipitation from underlying sulfide minerals. The revegetation efforts have been successful as the water quality of surface runoff from the site has improved and more untreated runoff can be directed off–site.

Figure 2–34. Photo of Summitville Site in 1980 Prior to SCMCI Operations



Source: Topper (2001), courtesy of IntraSearch, Inc.

Figure 2–35. Photo of Summitville Site in 1991 During Summitville Operations

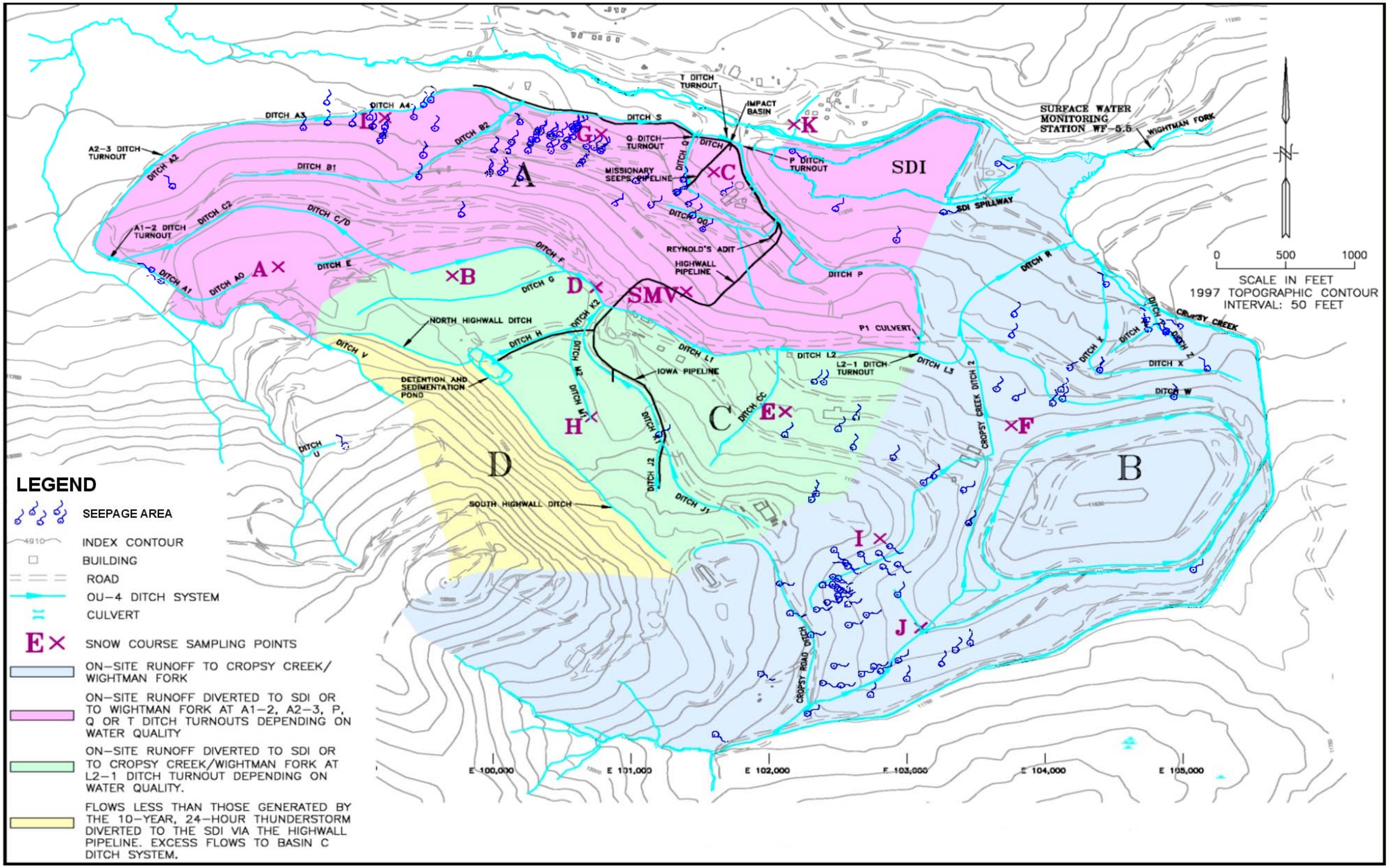
Source:Topper (2001), courtesy of IntraSearch, Inc.

The EPA has operated the treatment plant at the Summitville site since the bankruptcy of SCMCI in order to raise pH and remove metals from contaminated water draining from the Summitville site. Treatment of contaminated drainage from the pit highwall, adits, and seeps will be required for the foreseeable future. The treatment rate of the plant averaged 3.3 acre–feet per day in 2003 and has typically operated between mid–April and mid–October (CDPHE 2003b). The operation period for the plant targets the period of high runoff at Summitville, although the timing of runoff cannot be predicted. Starting water treatment at the site earlier in the year would be difficult due to snow on the roads and the layer of ice on the SDI. Starting the plant earlier would not necessarily be effective. The current timing is based on drawing down the water level in the SDI before the runoff to maximize available storage space in the SDI, but avoiding sucking up bottom sediments.

The Summitville dam impoundment (SDI) is used to capture contaminated mine drainage from the Summitville site before being pumped to the treatment plant. However, drainage from only a portion of the site can be directed to the SDI for treatment. **Figure 2–36** shows general drainage areas in the Summitville site. Drainage from the pit highwall area (area D) is directed to the SDI via a pipeline. Drainage from the northwest (area A and C) portion of the site is directed to the SDI via a series of ditches. However, drainage from the southeast portion of the site (indicated as area B) enters Cropsy Creek and travels to Wightman Fork without treatment. A large number of seeps are present in the untreated drainage area, and drainage from this area represents a contaminant source to the Alamosa River. However, underlying minerals in the southeast are less severely altered than the northwest portion of the site, and most of the area has been revegetated. During 2003, water quality samples (30) from lower Cropsy Creek below area B had a median pH of 4.84 and a median copper concentration of 282 μg/l.

The SDI has a storage volume of about 265 acre–feet (CDPHE, 2004). The SDI storage volume and the current treatment capacity are insufficient to treat all drainage from the northwest portion of the site during years of above–average snow–pack or even average years. As a result, Summitville operators have had to periodically release untreated water from the SDI during four of the last eight years. Water in the SDI is highly contaminated and currently has a pH of about 3 and a dissolved copper concentration of 30,000 μg/l (**Figure 2–73**). Recently, ditch turnouts were installed to allow drainage from the site to be released directly to Wightman Fork untreated. Turnout locations are also shown in **Figure 2–36.** Although most site drainage is highly contaminated, drainage water quality is significantly better than water contained in the SDI. Therefore, during periods of high snowmelt when an SDI release would be impending, releases from turnouts discharge less contamination than would a release from the SDI. Summitville operators monitor water quality at the turnouts and attempt to release waters with lower amounts of contamination. **Table 2-12** lists volumes of untreated releases from the Summitville site since 1996 as well as the load of copper released. Releases in 1997, 1998, 1999, and 2001 were from the SDI. The releases in 2004 were made through the ditch turnouts.

Figure 2-36. Summitville Drainage Areas and Seeps



Modified from CDPHE, 2004

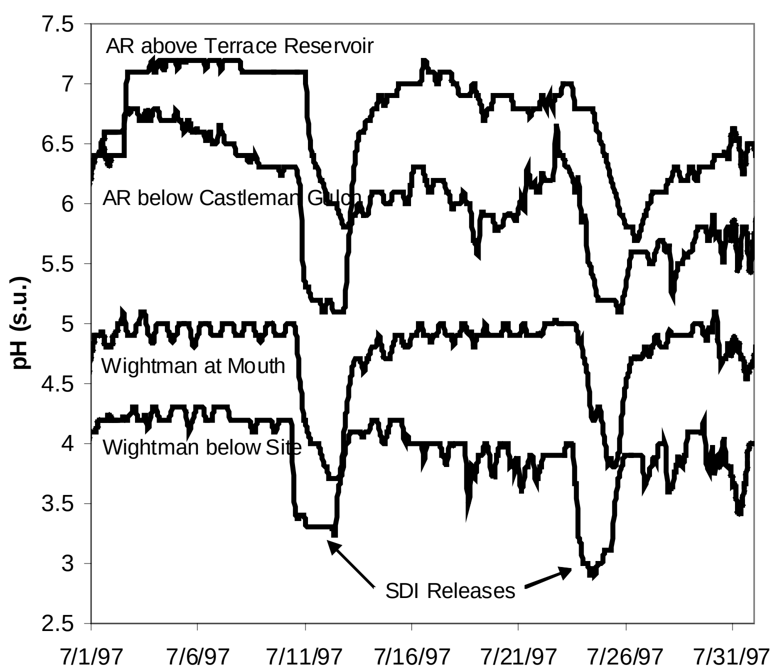
Table 2-12. Untreated Releases from Summitville Site

Year	Volume Released		Copper Load Pounds	Percent Snow Pack
	Gallons	Acre–ft		
1996	0	0	0	28%
1997	169,000,000	518	35,000	208%
1998	9,800,000	30	1,500	107%
1999	53,000,000	163	5,600	131%
2000	0	0		67%
2001	11,700,000	36	3,500	108%
2002	0	0		–
2003	0	0		59%
2004*	56,000,000	172	2,350	NA

Notes: Percent Snow Pack from Summitville course surveys, compared to Average snow pack.
Year 2002 snow pack was at historically low levels
*2004 release from ditch turn–outs rather than SDI
Source: (CDPHE, 2004)

Releases from the SDI have significant effects on the water quality in Wightman Fork and in the Alamosa River. Two small SDI releases from July 10–12, 1997 and July 23–25, 1997 were apparent in the USGS gages that were equipped with pH monitors in that time period. Precipitation events did not occur in this time period, so the cause appears isolated to the SDI releases. **Figure 2–37** shows the observed pH at stations in Wightman Fork and downstream of Wightman Fork. Water pH dropped by about 1 standard unit at all downstream sites in response to the July 10–12 release.

Figure 2–37. Impacts of SDI release on downstream pH in July 1997



Source: USGS gage data

Releases from the SDI have the potential to kill any fish populations in the Alamosa River downstream of Wightman Fork. The continued risk of SDI releases is high. The installation of ditch turnouts at the site lessens the risk of toxic impacts. However, releases from the turnouts can also discharge significantly contaminated drainage from the site. Therefore, the insufficient capacity of the SDI and the current treatment plant should still be considered a major problem, and all potential efforts should be taken to install a new treatment plant with both a higher treatment efficiency and capacity as well as increasing the storage volume of the SDI. Treatment of drainage from the southeast portion of the site should also be considered.

Historical Mining Areas Other than Summitville

In the Alamosa River watershed, mining occurred in the Summitville, Stunner, Gilmore, and Jasper mining districts. The Stunner and nearby Gilmore districts contained gold–silver ores and copper ores. Several small veins with gold, zinc, and lead ores were explored in the Jasper mining district. Mine production from the Stunner, Gilmore, and Jasper districts was relatively insignificant when compared to the highly mineralized Summitville district. However, several small mines and numerous prospects dot the upper Alamosa River watershed. Many studies document or examine historical mining areas in the Alamosa River watershed. The CGS conducted an extensive field inventory of mined areas outside of Summitville and characterized water quality impacts from many of the mines in 1993 and 1994. Data from this study were presented in Kirkham et al. (1995) and much of the data in the following section is drawn directly from this study.

A total of 219 mine openings and 130 mine dumps were inventoried during the CGS study, most of which were prospect features. Many prospects were only a few feet deep and most openings were caved in or small. After Summitville, the Pass–Me–By Mine was estimated to have the largest amount of underground workings as it had the largest dump with an estimated size of about 10,000 cubic yards (cy). The next largest dumps are at the Miser Mine, an unnamed mine near Burnt Creek, and the Eurydice Mine. The size of these dumps was estimated to be between 1000 cy and 10000 cy (Kirkham et al 1995) but accurate measurements were not available in the literature. Dumps of approximately 1,000 cy were found at the Asiatic, Guadaloupe, Globe, Red Mountain #1, and Sanger mines and at unnamed mines at the Watrous claims, two adits near Stunner campground, and two adits near Rd 250 near Alum Creek and north of Terrace Reservoir.

Water was draining out of or standing within 31 of the inventoried mine openings and from dumps at the Pass–Me–By Mine, the Watrous Claims, and at the un–named mine near Burnt Creek. **Figure 2–38** shows the location of major mines with flowing or standing water as well as locations of other small adits or prospects. Water samples were taken at these major mines, and discharge at the time of sampling was estimated. **Table 2-13** shows the water quality data from these samples as well as calculated contaminant loads. Mines were ordered in approximate order of the severity of contaminant loads in the table, but this order is subjective based on contaminants of concern.

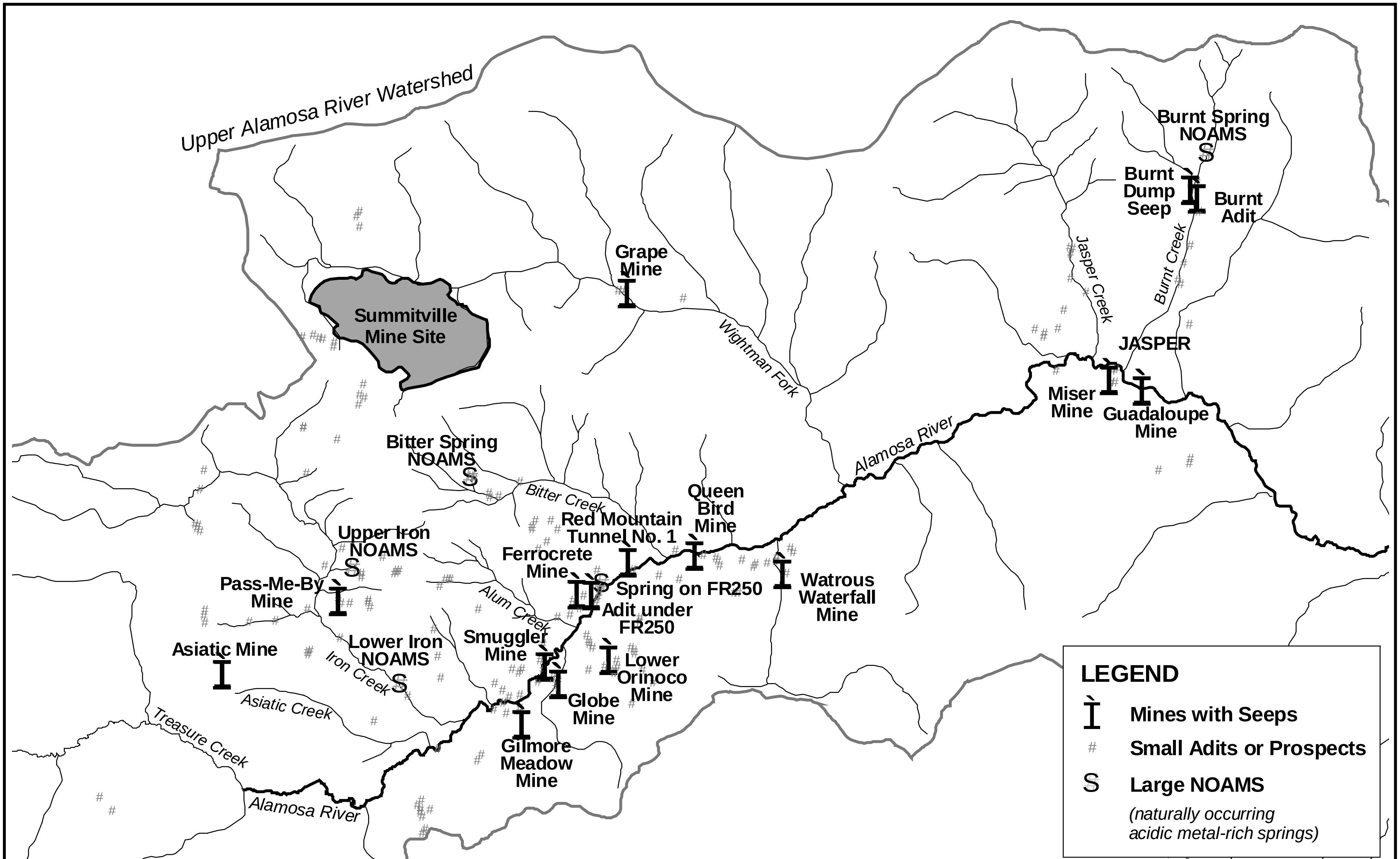
The Pass–Me–By Mine had the lowest pH and contributes the highest loads of copper, iron, and aluminum of any of the mining sites. Water discharges primarily from the collapsed portal of the mine and a small seep also forms below the mine dump. Water from the mine has killed areas of conifer trees and deposited a deep red precipitate. **Figure 2–39** shows a photo of drainage from the Pass–Me–By portal. The largest mine discharge issues from Miser Mine. **Figure 2–40** shows a photo of the Miser Mine red–orange discharge. The Miser discharge produces the highest loads of zinc and manganese of any of the mining sites. The discharge enters several beaver ponds which appear to remediate the discharge somewhat before entering the Alamosa River. Water discharging from the collapsed portal had a pH of 5.9, but water discharging from the beaver ponds had a pH of 7.4. However, the toxicity of the metal loading may impact the wetland at some point and treatment effectiveness may decrease in the future. The Guadaloupe Mine discharges relatively high loads of zinc, manganese, and iron. Relatively high loads of aluminum are discharged by the Ferrocrete and Asiatic Mines, and the Ferrocrete Mine and Red Mountain Tunnel No. 1 discharge relatively high loads of iron. The Watrous Waterfall Mine had the highest concentration of copper, and the Burnt Adit had the second lowest pH of the mine sites, but both were ordered near the bottom of the contaminant loadings due to small discharges.

Loads from historical mining are less significant on a watershed scale than loads from the Summitville site and from natural sources. **Section 2.4.9** presents estimates of metal loads contributed by natural sources as well as the sum of the loads estimated by Kirkham et al. for historic mines. Historic mines are estimated to contribute approximately 2.3% of the iron, 1.8% of the aluminum, 0.3% of the zinc, and 0.04% of the copper loads to the Alamosa River. Although the percentages are small, inactive mines have significant local impacts on Iron Creek, the upper Alamosa River, and upper Burnt Creek.

Table 2-13. Water Quality and Contaminant Loads from Mine Sites and Major Natural Springs

		Flow	Iron		Aluminum		Manganese		Copper		Zinc	
	pH	gpm	(μg/l)	lbs/year	(μg/l)	lbs/year	(μg/l)	lbs/year	(μg/l)	lbs/year	(μg/l)	lbs/year
MINE SITES												
Pass–Me–By Mine	3.02	26.9	140,000	16,516.0	59,000	6,960.3	310	36.5	78	9.21	180	21.24
Miser Mine	5.85	126.0	1,500	828.9	< 1,000	0.0	280	154.7	< 40	0.00	41	22.65
Guadaloupe Mine	6.39	1.9	22,200	185.0	330	2.7	3,464	28.9	105	0.88	2,511	20.92
Ferrocrete Mine	3.98	0.8	61,000	214.0	11,000	38.6	2,400	8.4	< 4	0.00	250	0.88
Asiatic Mine	6.00	5.8	790	20.1	1,000	25.4	420	10.7	< 40	0.00	< 40	0.00
Red Mountain No. 1	6.58	2.3	17,900	180.6	420	4.3	1,541	15.5	< 1	0.00	41	0.41
Adit under FR250	6.91	1.1	17,000	82.0	570	2.7	1,100	5.3	< 1	0.00	< 10	0.00
Globe Mine	6.40	1.5	810	5.3	60	0.4	1,000	6.6	< 4	0.00	240	1.58
Burnt Dump Seep	4.83	2.6	< 1,000	0.0	2,000	22.8	220	2.5	< 40	0.00	67	0.76
Gilmore Meadow Mine	5.29	0.8	2,900	10.1	100	0.3	220	0.8	10	0.03	150	0.52
Grape Mine	5.65	0.7	220	0.6	< 100	0.0	120	0.4	2	0.01	370	1.13
Lower Orinoco Mine	7.44	1.5	2,140	14.1	< 40	0.0	941	6.2	< 1	0.00	19	0.13
Queen Bird Mine	5.52	0.4	580	1.0	130	0.2	381	0.6	< 1	0.00	48	0.08
Burnt Adit Mine	3.10	0.1	5,000	2.2	5,000	2.2	460	0.2	100	0.04	58	0.02
Smuggler Mine	6.10	0.2	2,200	1.9	120	0.1	339	0.3	< 1	0.00	< 10	0.00
Watrous Mine	3.14	0.0	35,000	0.0	3,200	0.0	470	0.0	1,400	0.00	160	0.00
NATURAL SPRINGS												
Upper Iron Spring	2.53	6.7	160,000	4,701.3	120,000	3,526.0	240	7.1	990	29.09	260	7.64
Burnt Spring	3.82	18.0	70,000	5,683.7	31,000	2,447.1	4,200	331.5	58	4.58	810	63.94
Spring on FR250	2.75	3.9	70,000	1,197.3	38,000	649.9	15,000	256.5	350	5.99	930	15.91
Lower Iron Spring	2.94	20.0	26,000	2,280.5	9,000	789.4	650	57.1	< 40	0.00	130	11.40
Bitter Spring	3.27	1.6	1,920	0.0	1,420	10.0	49	0.2	77	0.54	138	0.97

Source: Kirkham et al. 1995



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Alamosa River Watershed Restoration Master Plan

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

Figure 2-38. Contaminant Point Sources Alamosa River Watershed

Source: Kirkham et al. 1995

Figure 2–39. Photo of Drainage from the Pass–Me–By Mine Portal

Figure 2–40. Photo of Drainage from the Miser Mine

Natural Contaminant Sources
The intensively altered areas of the Alamosa River watershed have probably impacted water quality to a certain degree for millions of years. The Jasper and Stunner altered areas have been extensively eroded. Large unprotected steep slopes in altered areas expose sulfide–rich minerals to oxidation and acid–production. The most intensely altered zone in the Stunner alteration surrounds Alum Creek, and nearly the entire profile of the altered zone has been exposed by deep erosion.

Figure 2–41 through **Figure 2–46** show oblique aerial photos of the primary tributaries draining hydrothermally altered areas from west to east; Iron Creek, Alum Creek, Bitter Creek, Wightman Fork, Jasper Creek, and Burnt Creek. Aerial photos were taken June 15, 2004. In addition to the major creeks, several smaller, more ephemeral tributaries also drain altered areas. A small creek between Iron Creek and Alum Creek is often referred to as Washout Creek because it often washes out the Forest Road 380 crossing. Several samples from the creek have indicated poor water quality. A small ephemeral tributary can also be noted on the aerial photos to the east of Alum Creek. A portion of the watershed of Spring Creek is in altered materials. The Alamosa River itself cuts through a portion of the Stunner altered area from Iron Creek to Bitter Creek (**Figure 2–33**). The river channel is primarily in the area of the igneous intrusion that formed the altered area and materials are less intensely altered than upper elevations to the north. However, groundwater base flows to the river in this area may originate in the intensely altered areas and may be of poor water quality.

Many naturally occurring acidic, metal rich springs (NOAMS) discharge contaminated waters directly to surface water sources. NOAMS range from seepage areas along streams to large springs that have formed mounds of "ferrosinter". **Figure 2–47** shows a photo of a ferrosinter mound in Burnt Creek that is brightly colored and a beautiful feature that should be protected from damage. A short distance downstream, a spring appeared to support a unique ecosystem adapted to the acidic environment (**Figure 2–48**).

Kirkham et al. sampled the water quality of several of the largest NOAMS and the results were included in **Table 2-13**. Springs were also listed in general order of contaminant loads. The locations of these NOAMS were included in **Figure 2–38**. The upper and lower springs on Iron Creek, the Burnt Spring, and the Spring on FR250 produced higher loads of iron and aluminum than all the inactive mines except the Pass–Me–By. In comparison to all the inactive mines, the Upper Iron Spring produced a higher load of copper, the Burnt Spring produced a higher load of zinc, and the Burnt Spring and Spring on FR250 produced higher loads of manganese.

Although several large "point" sources of natural contamination have been identified, the majority of natural water quality contamination enters surface water courses on a watershed scale as non–point sources. Base flows from groundwater and subsurface flows maintain acidic conditions in the altered tributaries. However, rainfall events tend to decrease pH (increase acidity) and increase metal concentrations to levels that can be acutely toxic to fish and aquatic organisms.

Rupert (2001) examined the effects of rainstorm events in the upper Alamosa River and in Wightman Fork. The effects were evaluated using continuous measurements of pH at stations on the Alamosa River from above Wightman Fork to below Terrace Reservoir and on Wightman Fork between 1995 and 1997. Rainfall events produced sharp and dramatic decreases in pH in upper altered areas of the watershed that propagated downstream. Although metal concentrations were only sampled periodically, increased concentrations of dissolved copper, iron, zinc, and aluminum were directly related to decreasing pH.

Figure 2–41. Aerial Photo of Lower Iron Creek

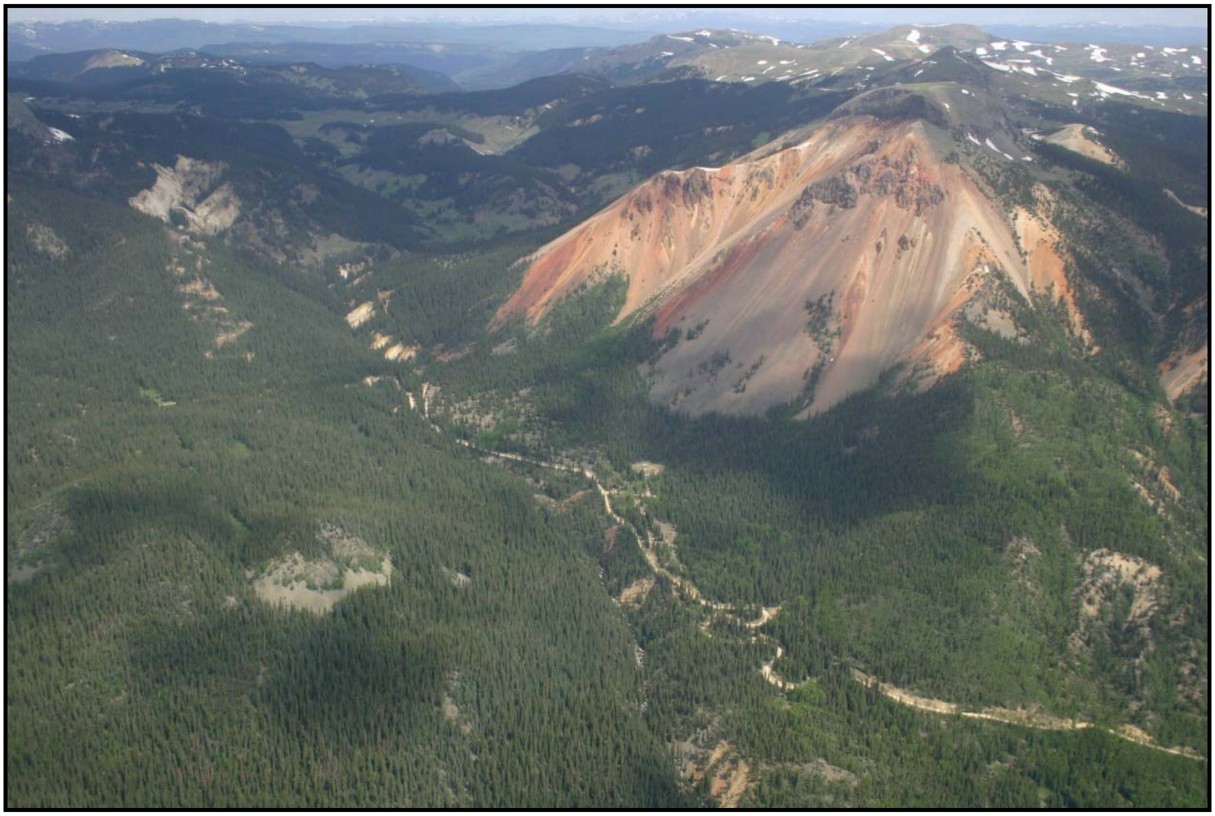


Figure 2–42. Aerial Photo of Alum Creek

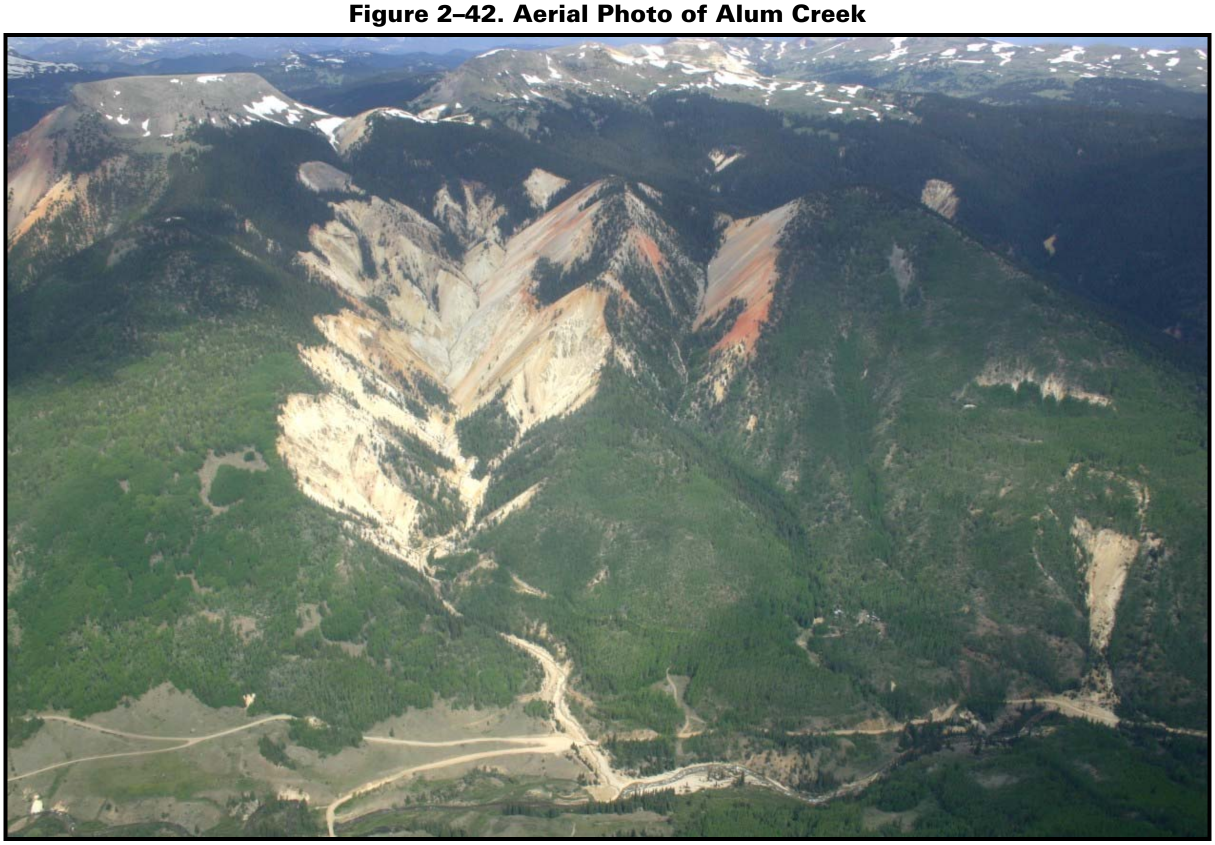


Figure 2–43. Aerial Photo of Bitter Creek

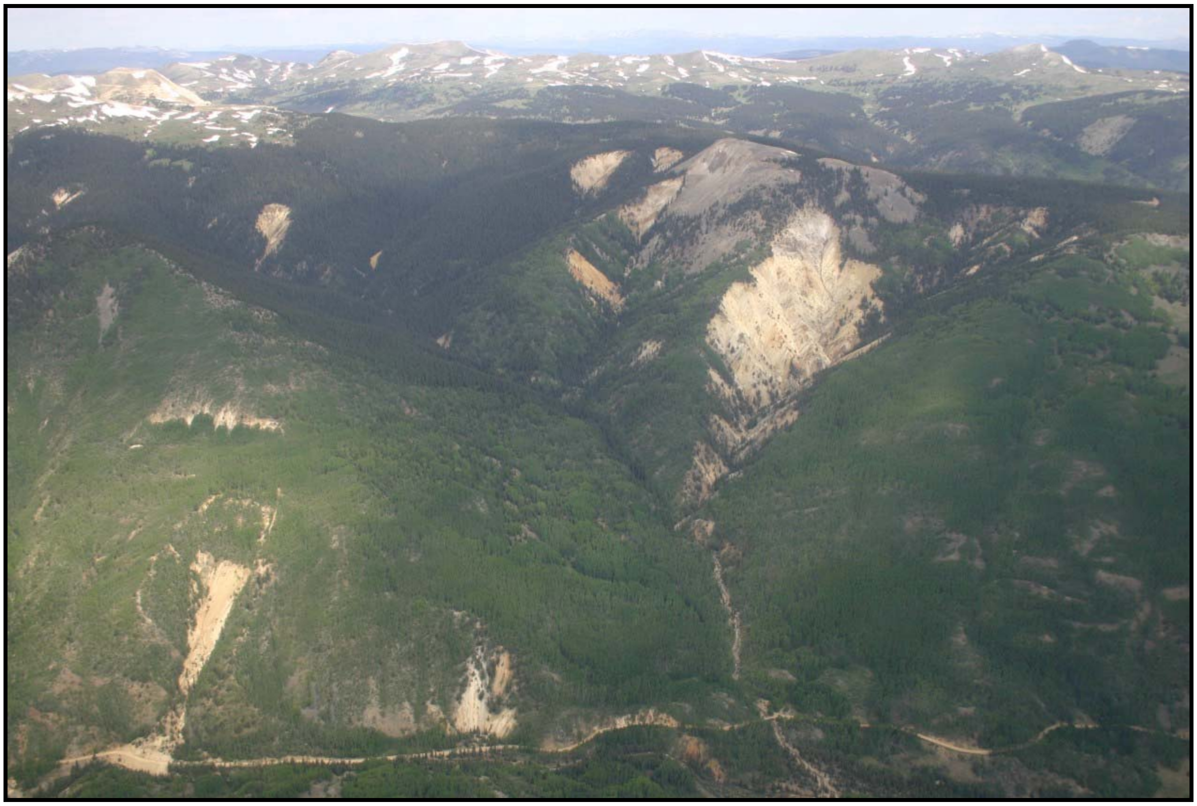


Figure 2–44. Aerial Photo of Wightman Fork

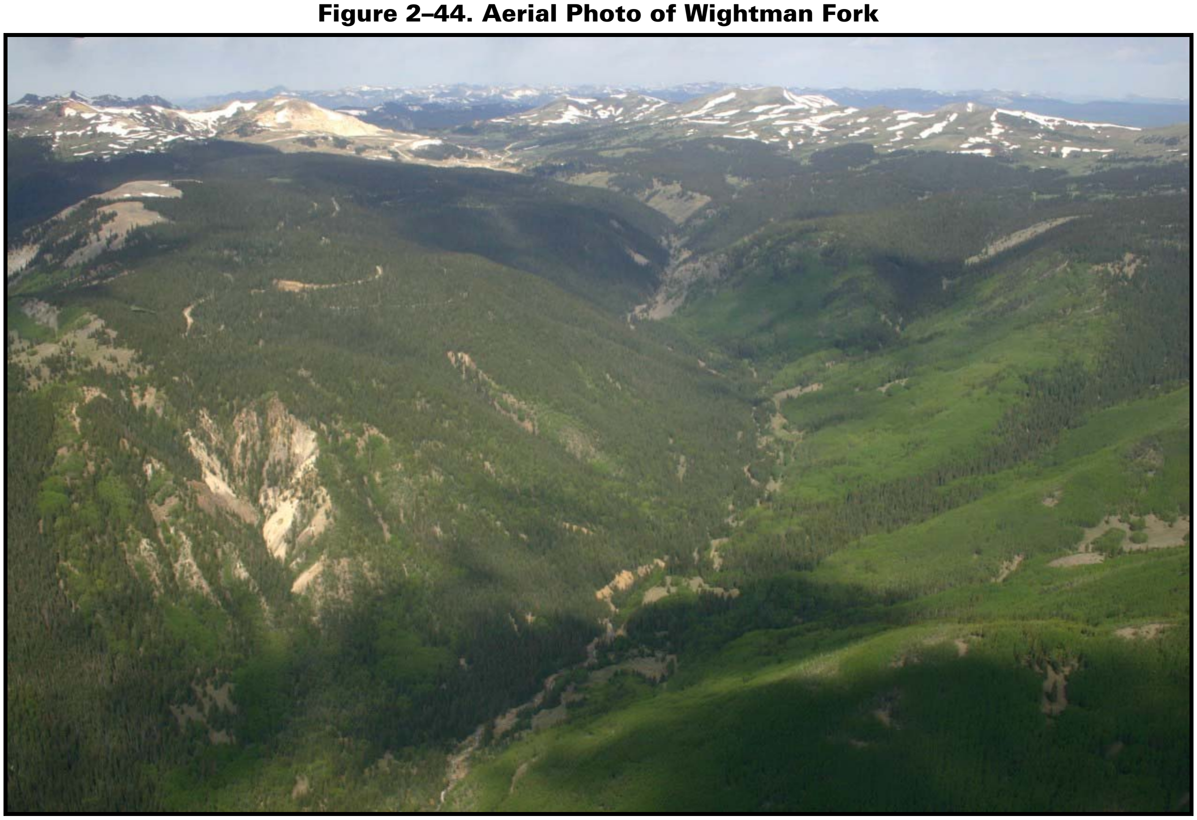


Figure 2–45. Aerial Photo of Upper Jasper Creek

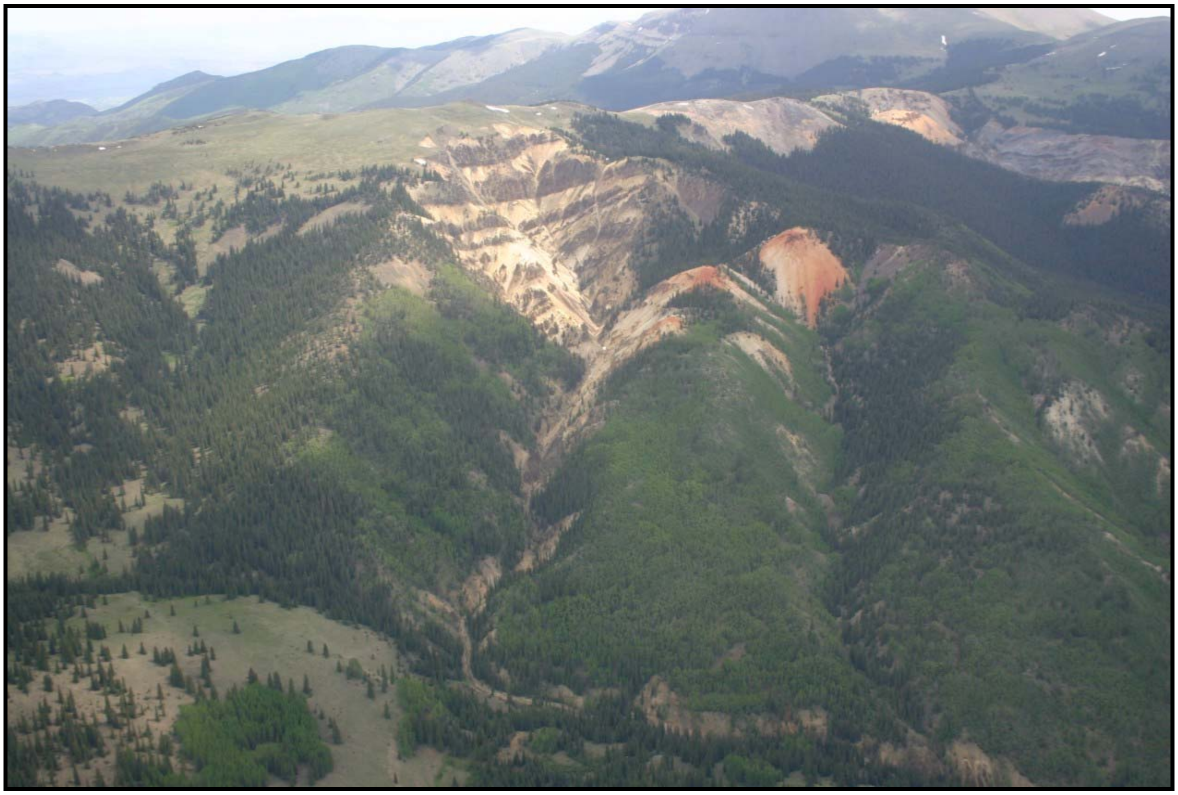


Figure 2–46. Aerial Photo of Upper Burnt Creek

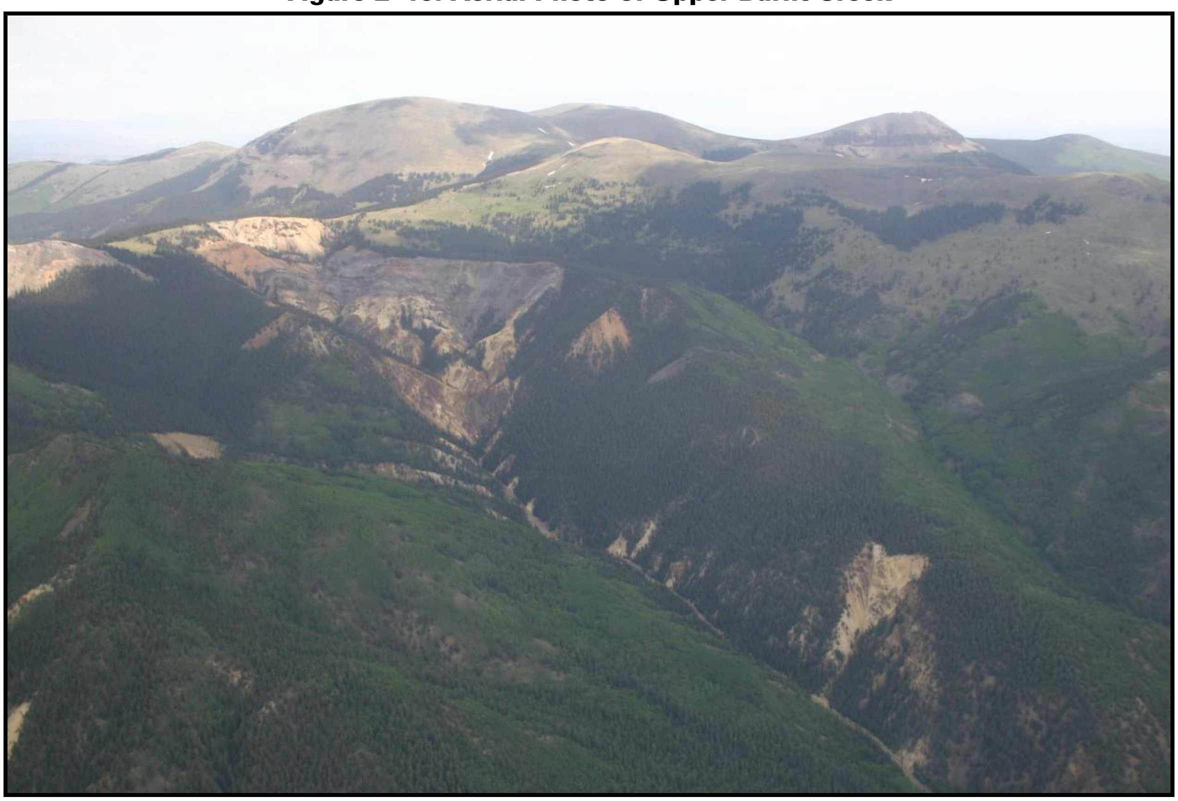
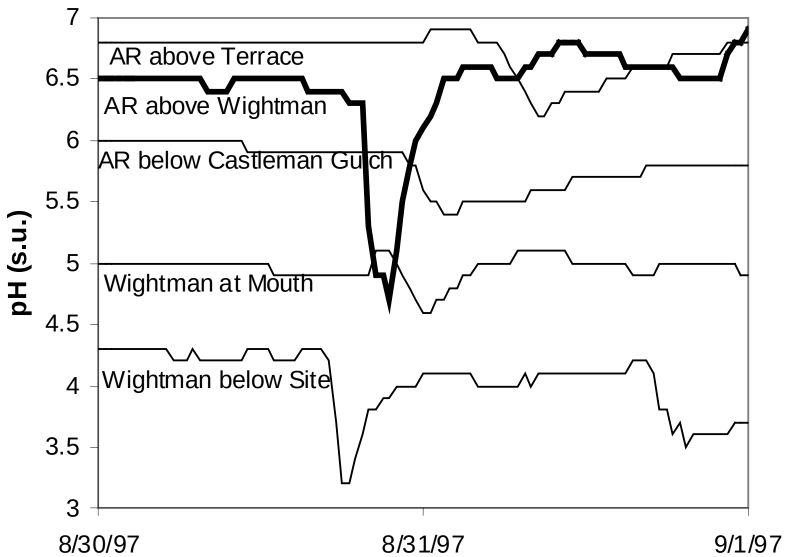


Figure 2–47. Photo of "Ferrosinter" Mound in Burnt Creek

Figure 2–48. Photo of Acidic Ecosystem in Burnt Creek

Figure 2–49 shows pH data collected by the USGS gages in late August 1997 during a rainfall event on the upper Alamosa Watershed. Runoff from the rainfall event increased flow in Wightman Fork from about 9 cfs to 25 cfs, in the Alamosa River above Wightman Fork from about 40 cfs to 80 cfs, and in the Alamosa River above Terrace Reservoir from about 65 cfs to 105 cfs. At the same time, the pH dropped from about 4.3 to 3.2 in Wightman Fork below Cropsy Creek and from about 6.5 to 4.5 in the Alamosa River above Wightman Fork.

Figure 2–49. Water pH in Response to Rainfall Event at USGS gages



Source: USGS Gage pH Data

The runoff peak became less acidic as it progressed downstream due to dilution by runoff from un–mineralized areas. The increasing pH is probably not due to reactions with the stream bed as channel materials are generally of volcanic origin and have little buffering capacity. This may have been confirmed during the one observed rain event that was limited to areas below the mineralized zones. During this rainstorm, the streamflow doubled at the Alamosa River above Terrace Reservoir gage, but the pH did not change (6.3) (Rupert 2001).

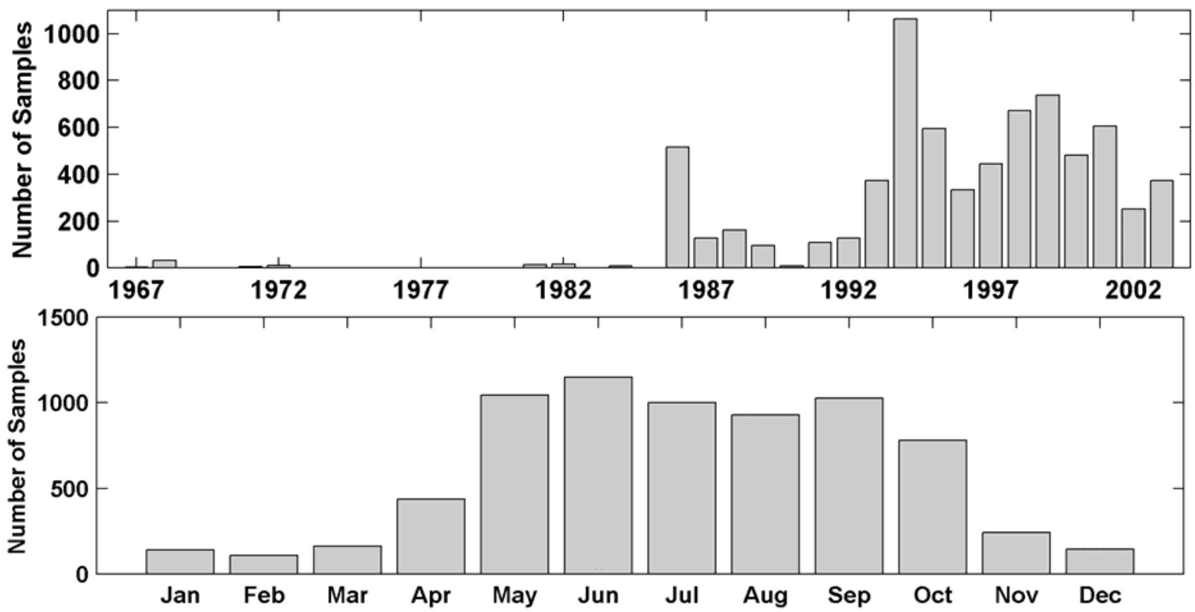
The sharp decreases in pH and increases in metal concentrations caused by rainfall events appear to be due to the washing of insterstitial and ground waters from mineralized areas that became very acidic between rainstorms (as suggested by Rupert) and/or by the rapid oxidation and liberation of acid by the rainfall itself as it flows through the mineralized soils to the stream. Fine mineralized sediments may also be washed into the stream course where they continue to oxidize.

2.4.4 Water Quality Data Methodology

For the current study, three sources of water quality data were compiled. The 1997 Use Attainability Analysis (UAA) (Posey and Woodling 1998) compiled 4,165 water quality samples for the Alamosa Watershed through year 1997. The majority of the samples were collected by the USGS and SLV Analytical, Inc. Sample location descriptions for samples collected from different sources varied widely. The UAA examined location descriptions and grouped adjacent sampling stations with a common river station identifier following the river stations traditionally used by the USGS. CDPHE also maintains a database of samples collected primarily by the USGS and contractors working for the CDPHE Hazardous Materials Waste Management Division (HMWMD). CDPHE data from 1998 to 2003 were added to the UAA database. The CDPHE WQCD has been collecting data downstream of Terrace

Reservoir at the Gomez Bridge since 1992. WQCD data collected between 1994 and 2000 were not included in either the UAA or CDPHE HMWMD databases and were also included in this study. For the CDPHE data sets, station location identifiers were noted similar to the identifiers included for the UAA data. A total of 7,321 water quality samples collected between 1967 and 2003 from sites in the Alamosa River watershed were compiled. **Appendix A** presents a summary of the number of samples by year for each station location, and the original location descriptions and collection agency by station location. **Figure 2–50** shows the distribution of compiled water quality samples by year and month. Very few samples were collected prior to SCMCI activities at Summitville, and the majority of samples where collected after the SCMCI bankruptcy. Winter months are under–represented somewhat in the data set.

Figure 2–50. Distribution of Compiled Water Quality Samples by Year and Month

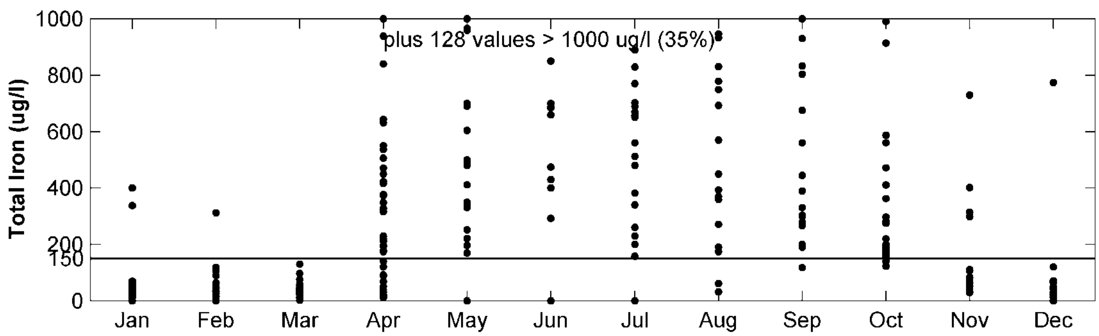


Similar to the UAA analysis, concentration data were compiled as micrograms per liter (μg/l) and all non–detect values were replaced with the value 0.001 μg/l. Detection limits varied widely and were typically above this value. However, replacing all non–detects with 0.001 μg/l and using median and percentile statistics reduces the effect that changing detection limits may have on observed trends.

With the exception of iron, water quality standards for metals are based on dissolved concentrations. Dissolved concentrations are determined after filtering samples through a 0.45 micron filter, and it is thought that the dissolved portions are more bio–available to aquatic organisms than particulates that may be included in total metal concentrations. However, many water quality samples for the Alamosa watershed were analyzed for total metal concentrations rather than dissolved. The UAA examined the correlation between dissolved and total metal concentrations, and found that for most data, dissolved metal concentrations were nearly equal to total metal concentrations. This is reasonable given the low pH conditions commonly found in the Alamosa River watershed. At low pH, nearly all metals are dissolved. The only exception to this might be storm events when sediment particulates containing metals are flushed into the stream courses. However, the majority of water quality data were not collected during storm events. Therefore, for analysis of water quality data, the 1997 UAA used total metal concentrations in place of dissolved concentrations when dissolved concentrations were not available. The UAA also noted that field observed pH is considered more appropriate than lab pH, but used lab pH for analysis when field pH was not available. These criteria were applied to the CDPHE data that were compiled for the current study.

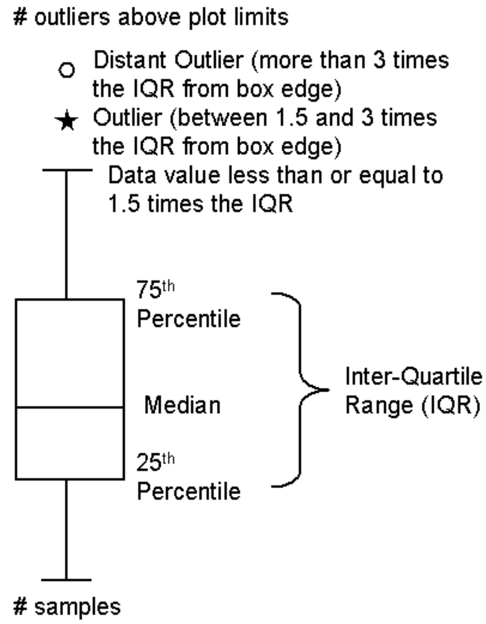
Water quality has been collected at stations below Terrace Reservoir throughout the year including winter months when the reservoir gates were closed. Although the reservoir gates have periodically leaked, water that is present in the winter below the dam is typically emanating from groundwater seepage and has different water quality characteristics than water from the reservoir and upper watershed that would be used downstream. Concentrations of total iron appear to correlate well with reservoir water. **Figure 2–51** displays total iron concentration data by month. Reservoir gates are usually shut during the entire months of December through March, and only 6 samples from these months had total iron concentrations greater than 150 μg/l. During summer months, total iron concentrations were almost always above 150 μg/l. Therefore, water quality data for samples collected between the months of December and March or with total iron concentrations less than 150 μg/l were not considered in statistical analyses below Terrace Reservoir.

Figure 2–51. Total Iron Concentration below Terrace Reservoir and Gomez Bridge by Month



Box and whisker plots are commonly used to describe the variation of water quality data around the median value and are used here to summarize data groups. A shaded box represents the inter–quartile range. The bottom and top of the box represents the 25th and 75th percentile of the data, respectively, and a line within the box represents the median of the data. The top and bottom of the "whiskers" represents the furthest data point within 1.5 times the inter–quartile range outside of the box (quartile). Outliers within 1.5 to 3 times the inter–quartile range outside of the box are represented by a star and distant outliers more than 3 times the inter–quartile range outside of the box are represented by an open circle. For box and whisker plots in this report, the number of samples in each data set is noted below the plot and the number of outliers above the plot limits is noted above the plot. **Figure 2–52** shows a schematic of a box and whisker plot.

Figure 2–52. Box and Whisker Plot Schematic



2.4.5 Water Quality Standards

The CDPHE Water Quality Control Commission (WQCC) has established use classifications for the Alamosa River and its tributaries as well as numeric standards that are based on protection of the designated use. In the past several years, the WQCC has proposed numerous changes in segments, use designations, and water quality standards. The 1997 UAA proposed several changes to water quality standards to reflect, in its opinion, natural background levels of contaminants in the watershed that are irreversible. Numerous local citizens and groups issued comments opposed to the less stringent water quality classifications, and several changes were withdrawn pending further analysis.

Figure 2–53 shows current CDPHE stream segments of the Alamosa River. Use classifications for these segments and complete numerical standards by stream segment are provided in **Appendix B** as presented in CDPHE 2003 effective January 20, 2003. Several studies have identified critical water quality parameters that are of particular concern in the Alamosa River watershed. Critical parameters have included pH, copper, iron, aluminum, cadmium, lead, manganese, and zinc. A summary of water quality standards for these parameters grouped by similar stream segment is presented in **Table 2-14**. Many standards are referenced to a Table Value Standard (TVS). The table value standards are also provided in **Appendix B** and are usually an exponential equation dependent on hardness. CDPHE considers that an instream standard has been exceeded if 15 percent of a representative data set over a 5 year period exceeds the numeric value (A. Ross, CDPHE WQCD oral commun, 2004). Therefore, the 85^{th} percentile value of a concentration data set is compared to evaluate exceedence of CDPHE instream standards. For pH, the 15^{th} percentile would be the appropriate value for comparison in acidic conditions.

Water quality standards are protective of aquatic species such as trout in the headwaters of the Alamosa River above Alum Creek, in Terrace Reservoir and the Alamosa River downstream of Terrace Reservoir and in tributaries that are not considered altered. From these levels, the iron standard is relaxed upstream of Terrace Reservoir, and the copper standard is relaxed upstream of Fern Creek to Wightman Fork presumably to reflect natural background levels of these metals. The naturally degraded conditions between Alum Creek and Wightman Fork are reflected in the removal of copper and aluminum standards and a significantly relaxed pH standard. Nearly all standards are relaxed or removed in the altered tributaries of Alum Creek, Bitter Creek, Jasper Creek, Burnt Creek, the lower reaches of Iron Creek, and Wightman Fork below Summitville. Wightman Fork above Summitville retains the strict standards with the exception of a relaxed pH standard.

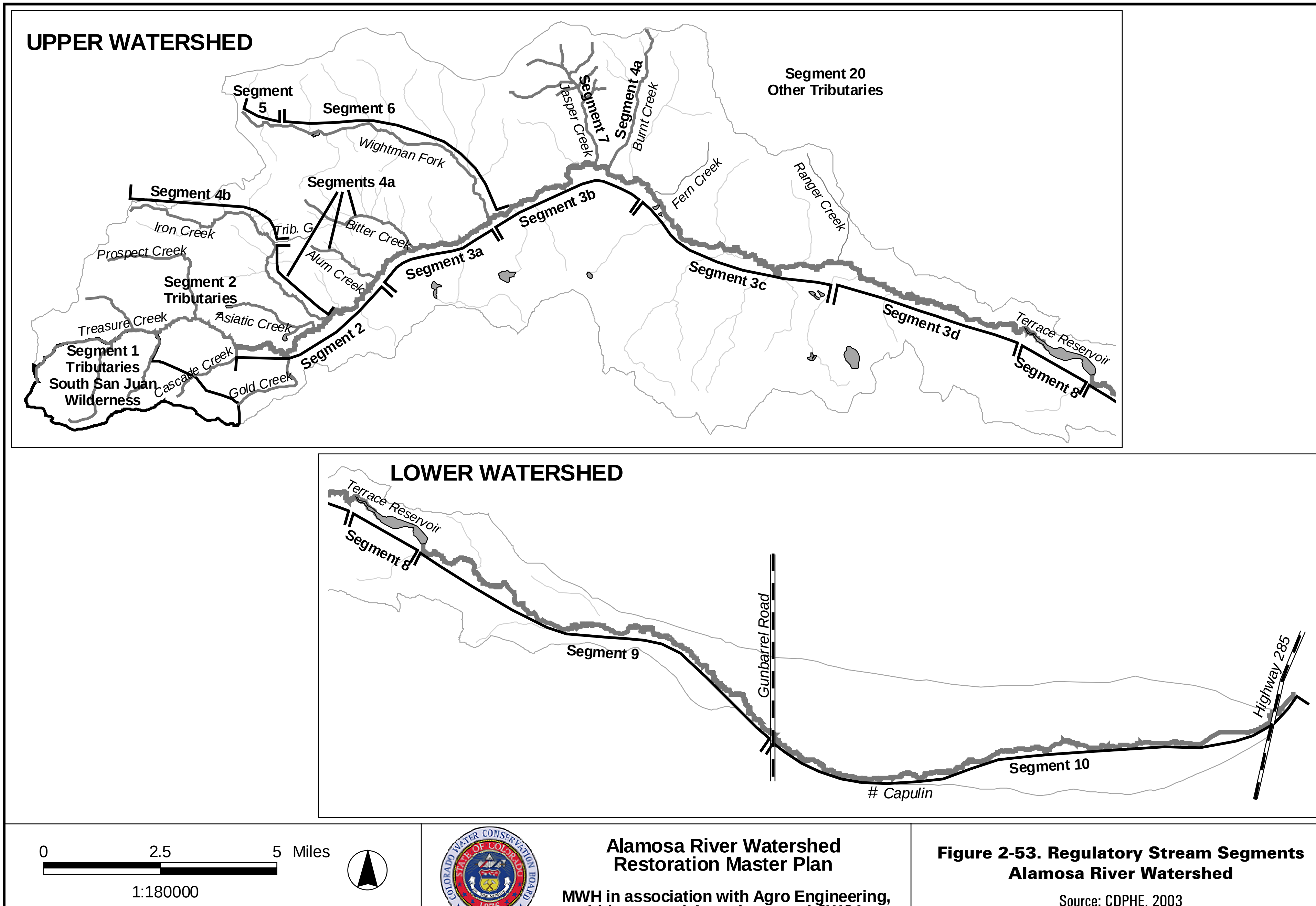
Water quality standards are provided in figures characterizing water quality data in the Alamosa River mainstem for comparison. As mentioned, most standards (TVS) for trace metals depend on hardness. Hardness values were provided with only a limited number of water quality data. If calcium and magnesium data were available for a sample, a hardness value was calculated as the sum of calcium and magnesium concentrations expressed as calcium carbonate. Values of hardness greater than 400 mg/l were replaced with the value of 400 mg/l in the average as directed by CDPHE 2003. The average hardness in the data set for a reach and time period was used to estimate an "average" standard value appropriate for that reach.

Total Maximum Daily Loads (TMDLs) have not been established by the WQCC for the Alamosa River. There has been interest in the community for the WQCC to issue these TMDLs. A draft version of TMDLs may be produced by fall 2004, but formal public notice is not anticipated in 2004 (Ross, 2004). Although TMDLs are important for watersheds with water quality problems, there are no National Pollutant Discharge Elimination System (NPDES) permits in the Alamosa River watershed. Therefore, there would be little mechanism for enforcement of TMDLs to achieve changes in water quality. However, TMDLs would provide objective targets for contaminant loads from the Summitville site or any potential new mines.

Table 2-14. Summary of Critical Water Quality Standards for Alamosa River

Segment	Uses	pH	Cu (ac)	Cu (ch)	Fe (ac)	Fe (ch)	Al (ac)	Al (ch)	Cd (ac)	Cd (ch)	Pb (ac)	Pb (ch)	Mn (ac)	Mn (ch)	Zn (ac)	Zn (ch)
1,2	1,3,4,5	6.5–9.0	TVS	TVS	WS(dis)	1000(Trec)			TVS(tr)	TVS	TVS	TVS	WS(dis)	TVS	TVS	TVS
3a	2,3,5	3.52[1] 4[2] 4.73[3] 3.94[4]	TVS			12000(Trec)	750		TVS(tr)	TVS	TVS	TVS	TVS	TVS	TVS	TVS
3b	1,3,5	6.5–9.0	TVS	30		12000(Trec)	750	87*	TVS(tr)	TVS	TVS	TVS	TVS	TVS	TVS	TVS
3c,3d	1,3,5	6.5–9.0	TVS	TVS		12000(Trec)	750	87	TVS(tr)	TVS	TVS	TVS	TVS	TVS	TVS	TVS
4a	3,5	2.5														
4b	1,3,5	6.5–9.0	TVS	TVS		1000(Trec)			TVS(tr)	TVS	TVS	TVS	TVS	TVS	TVS	TVS
5	1,3,5	6.0	TVS	TVS		1000(Trec)			TVS(tr)	TVS	TVS	TVS	TVS	TVS	TVS	TVS
6	3,5															
7	2,3,5	5.5		90(Trec)		3400(Trec)				1	4			1000		170
8	2,3,5	6.5–9.0	TVS	TVS		1000(Trec)	750	87	TVS(tr)	TVS	TVS	TVS	TVS	TVS	TVS	TVS
9	1,3,5	6.5–9.0	TVS	TVS		1000(Trec)	750	87	TVS(tr)	TVS	TVS	TVS	TVS	TVS	TVS	TVS
10	2,3,5	6.5–9.0	TVS	TVS		1000(Trec)	750	87	TVS(tr)	TVS	TVS	TVS	TVS	TVS	TVS	TVS

Notes: all metals concentraions are listed in μg/l
ac = acute standard; ch = chronic standard (standards not to be exceeded more than once in every three years on average)
TVS = Table Value Standard
Trec = total recoverable
dis = dissolved
tr = TVS for trout
WS = Less restrictive of existing water quality as of January 1, 2000 or 300 μg/l dissolved for Iron or 50 μg/l dissolved for Manganese
pH Segment 3a: 1 = December through February, 2 = March through May, 3 = June through August, 4 = September through November
Chronic Aluminum: * = Effective only May through September
Uses: 1 = Aquatic Life Coldwater 1, 2 = Aquatic Life Coldwater 2, 3 = Recreation 1a, 4 = Water Supply, 5 = Agriculture
Source: CDPHE 2003



Alamosa River Watershed Restoration Master Plan

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

Figure 2-53. Regulatory Stream Segments Alamosa River Watershed

Source: CDPHE, 2003

Effects of Water Quality on Aquatic Biology

Walsh (1997) prepared a review of water quality effects on aquatic biology related to the Alamosa River for the Valle del Sol Community Center in Capulin. Much of the information in the following paragraphs is drawn from that report.

Metals in water can exist in several forms depending on many factors including temperature, pH, and dissolved oxygen. Metals can be freely dissolved, dissolved as complexes with inorganic and organic matter, as colloids (a very fine suspended particle that does not readily settle), or attached to particulate matter. Toxicity effects are most related to the dissolved fraction as it is most bioavailable. Water quality standards are often expressed as acute or chronic. Acute toxicity causes mortality or extreme physiological disorders immediately following exposure. Chronic toxicity implies a longer term effect and may accumulate over time. Many toxicity tests refer to a "LC" value over an exposure duration. For example, a 96hr–LC50 would imply that the water quality level led to 50% of the test organisms dying over a 96 hour exposure. An LC value implies acute toxicity.

Dissolved metals such as copper, zinc, and aluminum cause fish mortality primarily in two ways: 1) by causing physical damage to the gills, or 2) by affecting the ability for the fish's gills to retain salts. Direct damage to gills impairs respiration which increases stress on the cardiovascular system leading to mortality. Metals inhibit the ability of gills to control the diffusion of salts into the water and inhibits uptake of these ions from the water; trout will generally die after losing 50% of their sodium. The effects of dissolved iron are not particularly detrimental. However, precipitation of iron hydroxide on to sediment and directly onto biota can have toxic effects. Cementation of bottom gravels can make areas unsuitable for spawning, and precipitates can cover gills, eggs, and newly hatched fry to the point of mortality. Low pH has effects similar to dissolved metals in that it reduces the ability of gills to retain electrolytes.

On the other hand, increased water hardness decreases the toxicity of metals and acts as a buffer against trace metals. Hardness is defined as the sum of multivalent metal cations; primarily calcium and magnesium, expressed as calcium carbonate. Calcium and magnesium ions compete with the other metals for binding sites on gills, thus reducing the toxicity effects of the trace metals. Therefore, water quality criteria for metals such as copper and zinc are usually expressed as exponential equations based on hardness.

Walsh (1997) noted the levels of copper, zinc, aluminum, and pH that caused acute toxic effects in trout in numerous tests referenced in the literature. From this literature review, Walsh noted that lethally toxic (96hr–LC50) effects to trout can be expected at copper levels between 15 and 80 μg/l, at zinc levels between 433 and 551 μg/l, at aluminum levels between 500 and 3500 μg/l, and at iron levels between 410 and 1700 μg/l; depending on hardness and water pH typical in the Alamosa River. For water pH, Walsh expected toxicity effects to trout at pH below 5.0. These standards were generally referenced to rainbow and brown trout. Brook trout are generally more tolerant to water pH and higher metals concentrations. It should be noted that these are "acute" toxicity levels at which mortality is expected over a 96 hour exposure. Levels at which populations could reproduce and remain viable should be well below these levels.

Ortiz and Ferguson (2001) listed toxicological reference values (TRVs) for both acute and chronic toxicity that were developed for a Summitville risk analysis considering both trout and benthic macroinvertebrates. The pH TRVs for rainbow trout were listed as 4.2 for acute toxicity and 5.6 for chronic toxicity and the pH TRVs for benthic macroinvertebrates as 5.38 for acute toxicity and 6.5 for chronic toxicity (equal to the CDPHE standard). TRVs for pH for sensitive aquatic species were provided in several figures comparing water quality to water quality standards.

2.4.6 Water Quality Changes Related to Summitville

Open pit mining and cyanide heap leaching at Summitville caused significant impacts to water quality in the Alamosa River. Therefore, prior to a more thorough examination of current conditions in the Alamosa River, historical changes in water quality below the Summitville site are first considered.

Pre–Mining Conditions

An understanding of water quality conditions prior to mining operations is important for the development of remediation goals in the Alamosa River. Unfortunately, few water quality measurements are available prior to the activities of SCMCI at Summitville, and it is difficult to quantify the impacts of mining. Medine (1997) attempted to assess pre–mining and pre–SCMCI water quality conditions in Wightman Fork and the Alamosa River below Wightman Fork as part of the 1997 UAA. Pre–mining conditions were estimated by combining water quality observed in upper Wightman Fork with representative water quality from Upper Cropsy, Alum, Bitter, and Iron Creeks to represent the naturally altered conditions near Summitville prior to mining. Pre–SCMCI conditions were estimated based on water quality samples collected between 1980 and 1987. Medine noted that heap leach operations were not observed in Wightman Fork until 1988, but some objections have been raised to these estimates as construction began on the heap leach facility in 1984 and operations began in the summer of 1986. Medine used the EPA. Water Analysis Simulation Program, Version 4 computer model to estimate downstream water quality by season given effects of adsorption, advection, dilution, and dispersion. The average of the four seasonal water quality estimates is provided in **Table 2-15**. Medine noted that these conditions would have been adequate to support a fishery in the Alamosa River prior to mining and would likely have supported a fishery in the river downstream of Fern and Spring Creeks prior to SCMCI activities.

Table 2-15. Water Quality Estimates for Period Before Mining and SCMCI Activities

Site:	Wightman below Site		Wightman at Mouth		AR below Wightman		AR above Terrace	
Period:	A	B	A	B	A	B	A	B
Cu	21	2,143	9	520	17	144	3	12
Zn	87	1,068	36	450	50	103	41	65
Fe–T	1,330	6,598	463	2,978	4,703	5,065		
Mn	295	2,385	117	1,005	274	367		
Al	860	1,513	363	710	1,381	1,413		

Notes: Estimated 85th percentile values in μg/l
A = before mining in watershed, B = before SCMCI activities at Summitville
Source: Medine 1997

Changes Due to SCMCI Activities and Remediation

Open pit mining at the Summitville site by SCMCI exposed a large area of highly altered materials to sulfide oxidation by surface and ground waters and increased the production of acidic metal laden runoff. As a result, water quality in Wightman Fork and the Alamosa River downstream of Wightman Fork experienced tremendous changes in water quality.

The Reynolds Adit was completed in 1897 under the Summitville Site as an access to underground mine workings and for mine drainage. The adit has long been a primary source of contamination in Wightman Fork. However, concentrations and loadings from the adit increased significantly as a result of SCMCI activities. **Figure 2–54** shows dissolved copper concentrations during SCMCI activities as well as the period of emergency response measures following bankruptcy in December 1992 until the Reynolds adit was plugged in winter of 1994. Average copper concentrations in data available prior to 1988 in the adit were about 15,000 μg/l. However, copper concentrations reached 364,000μg/l in 1992 and 652,000 μg/l in 1993 following abandonment of the site by SCMCI. Medine (1997) estimated that 82 percent of the load from the Reynold's adit during SCMCI operations could be attributed to SCMCI operations with the remaining 18 percent attributed to previous mining activities.

Figure 2–54. Dissolved Copper Concentrations in Reynolds Adit by Year

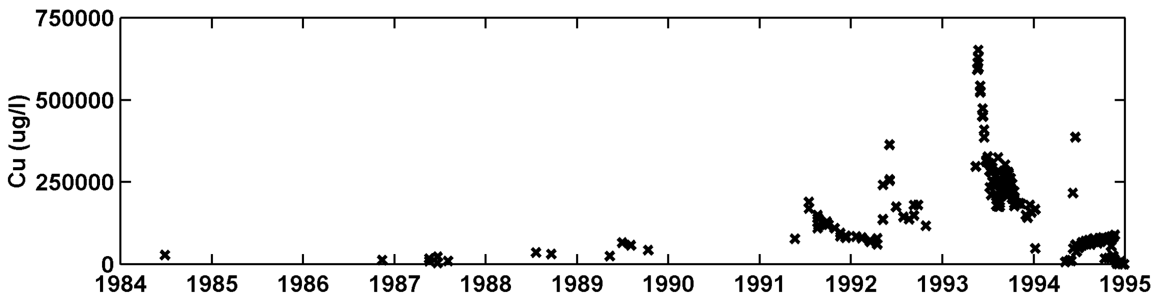
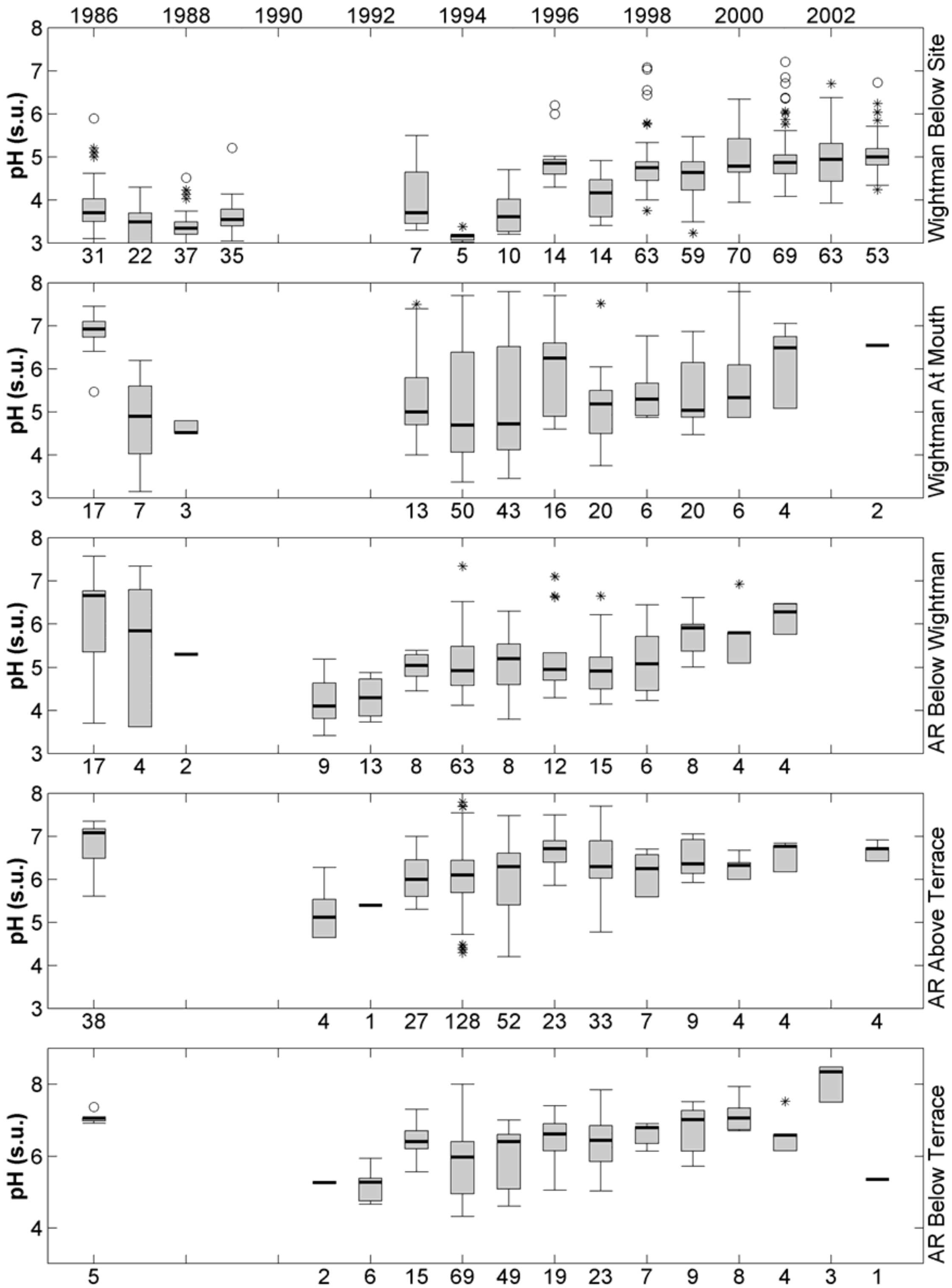


Figure 2–55 through **Figure 2–60** show changes in pH, copper, zinc, iron, manganese, and aluminum from 1986 through 2003 by year at selected locations downstream of the Summitville site. For parameters other than pH, estimates of water quality prior to mining and prior to SCMCI activities are also included as produced by Medine (1997). The pre–mining and pre–SCMCI box plots show the maximum and minimum seasonal estimate as well as the average seasonal value as shown in **Table 2-15**. There is very little water quality data prior to 1986, and 1986 corresponds to initiation of the heap leach operation by SCMCI.

A significant degradation in water quality in Wightman Fork and the Alamosa River can be observed following SCMCI operations through about 1995. Field pH reached as low as 2.4 below the Summitville site in 1987, 3.4 in the Alamosa River below Wightman Fork in 1991, and 4.3 and 4.6 in the Alamosa River above Terrace Reservoir and below Terrace Reservoir, respectively, in 1994. Dissolved copper concentrations reached levels as high as 37,000μg/l below the Summitville site in 1993, and 4,500 μg/l and 1,010 μg/l in the Alamosa River above Terrace Reservoir and below Terrace Reservoir, respectively, in 1994. Similarly to copper, levels of zinc, iron, aluminum, and manganese also rose significantly below the Summitville site following SCMCI activities.

Figure 2–61 and **Figure 2–62** group data from the 1986 to 1995 period by water quality stream segment with additional breaks at altered tributaries. Water quality standards are also plotted by stream reach using the average hardness calculated for the respective segment. Toxicological reference values (TRVs) for benthic macroinvertebrates and rainbow trout are plotted for pH, and the top chronic TRV for benthic macroinvertebrates corresponds to the pH standard of 6.5 (except for stream reach 3a). All years of available data were used for locations above Wightman Fork as conditions haven't changed significantly over the period of record. During the 1986 to 1995 period, median concentrations of metals and acidity increased in the downstream direction in the Alamosa River between the reach above Wightman Fork to the reach below Wightman Fork. Concentrations of copper in the Alamosa River below Wightman Fork reached levels such that the water quality standards cannot be noted on the same scale. Water pH, zinc, aluminum, and cadmium also regularly exceeded water quality standards in the Alamosa River below Wightman Fork in this time period.

Figure 2–55. Water Quality Downstream of Summitville by Year – pH

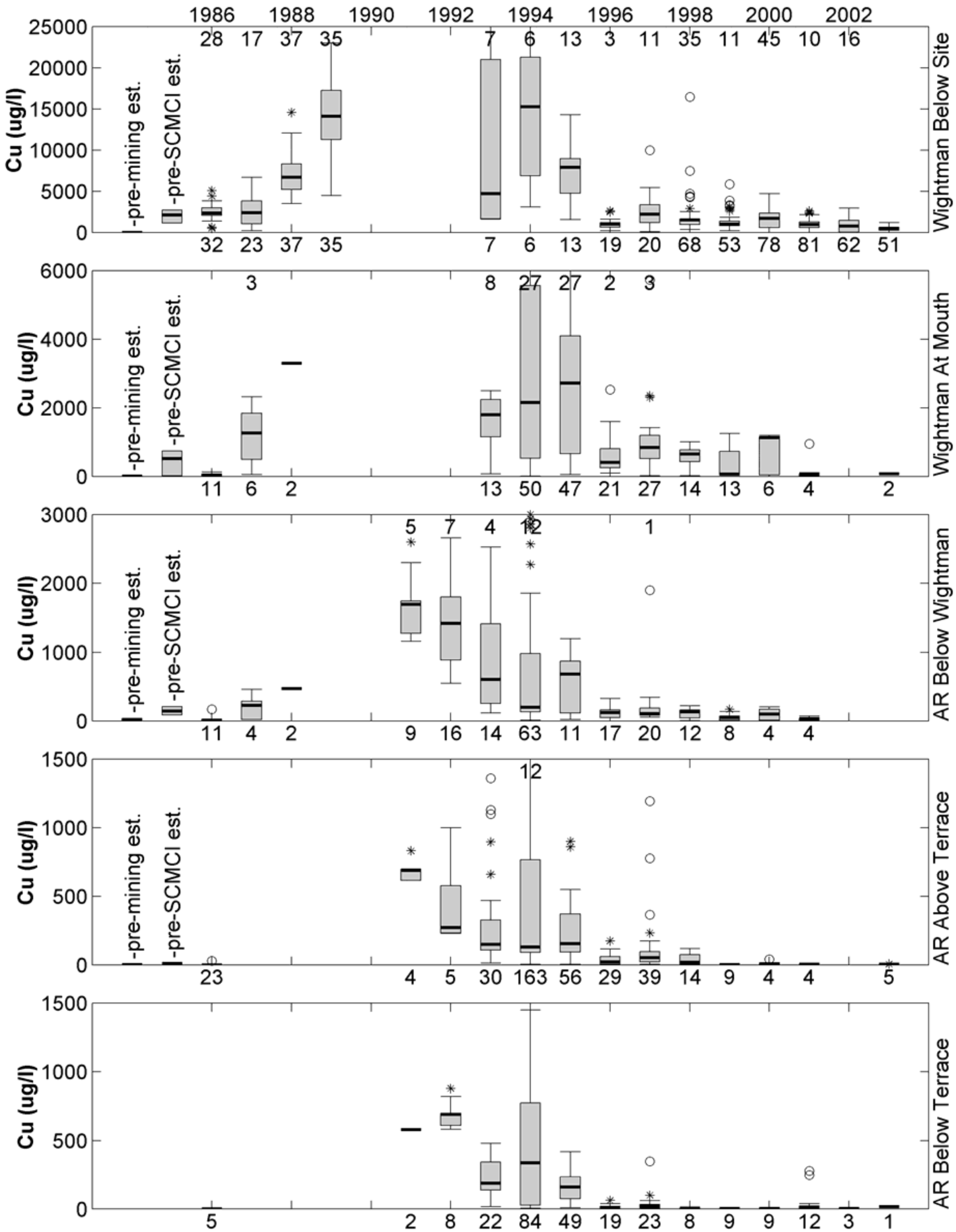


Notes: Alamosa River below Wightman includes all data between Jasper Creek and Wightman Fork

Alamosa River above Terrace includes all data between Terrace Reservoir and Jasper Creek

See Appendix H for information on interpreting box–whisker plots

Figure 2-56. Water Quality Downstream of Summitville by Year - Dissolved Copper

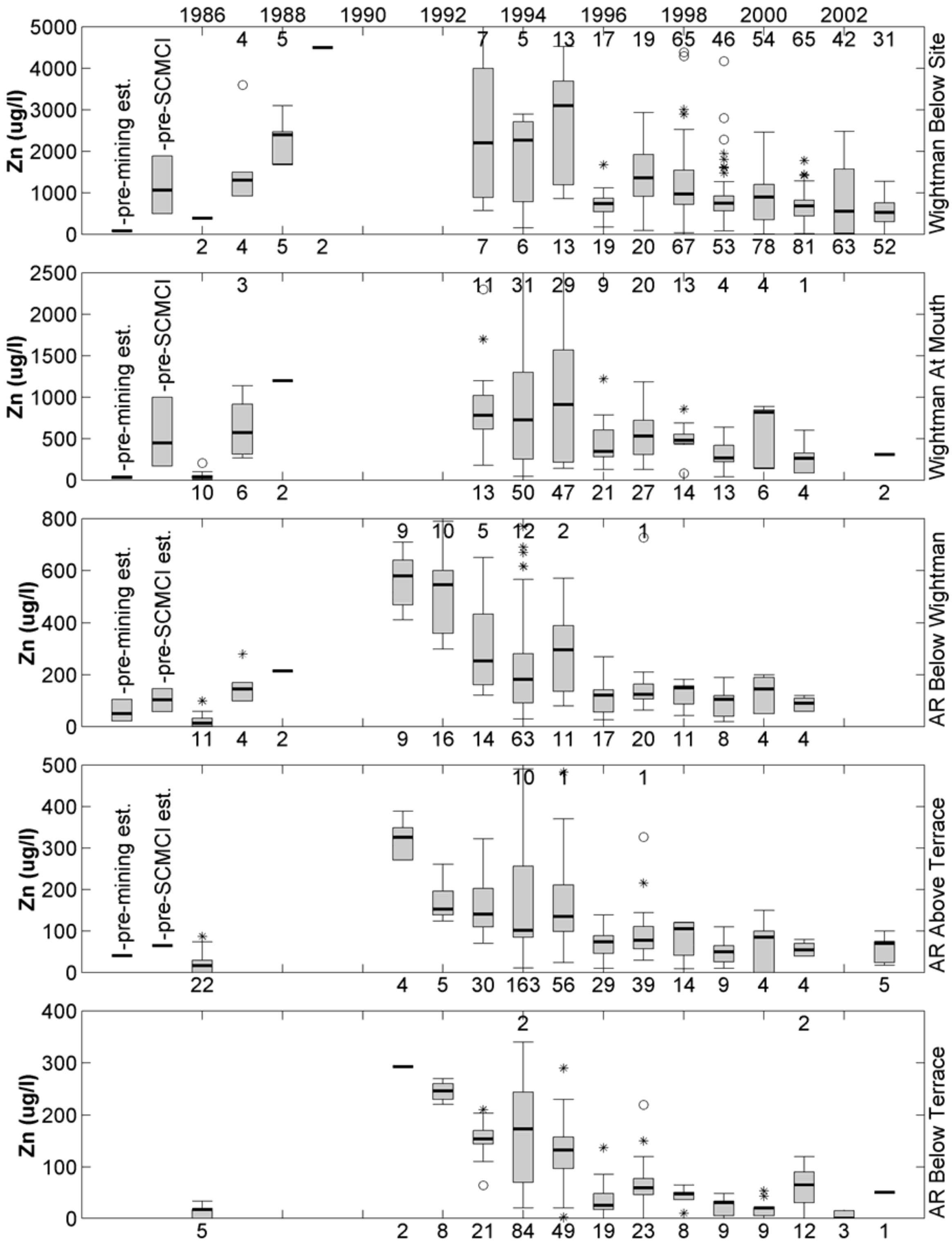


Notes: pre-mining and pre-SCMCI estimates from Medine (1997)

Alamosa River below Wightman includes all data between Jasper Creek and Wightman Fork

Alamosa River above Terrace includes all data between Terrace Reservoir and Jasper Creek

Figure 2–57. Water Quality Downstream of Summitville by Year – Dissolved Zinc

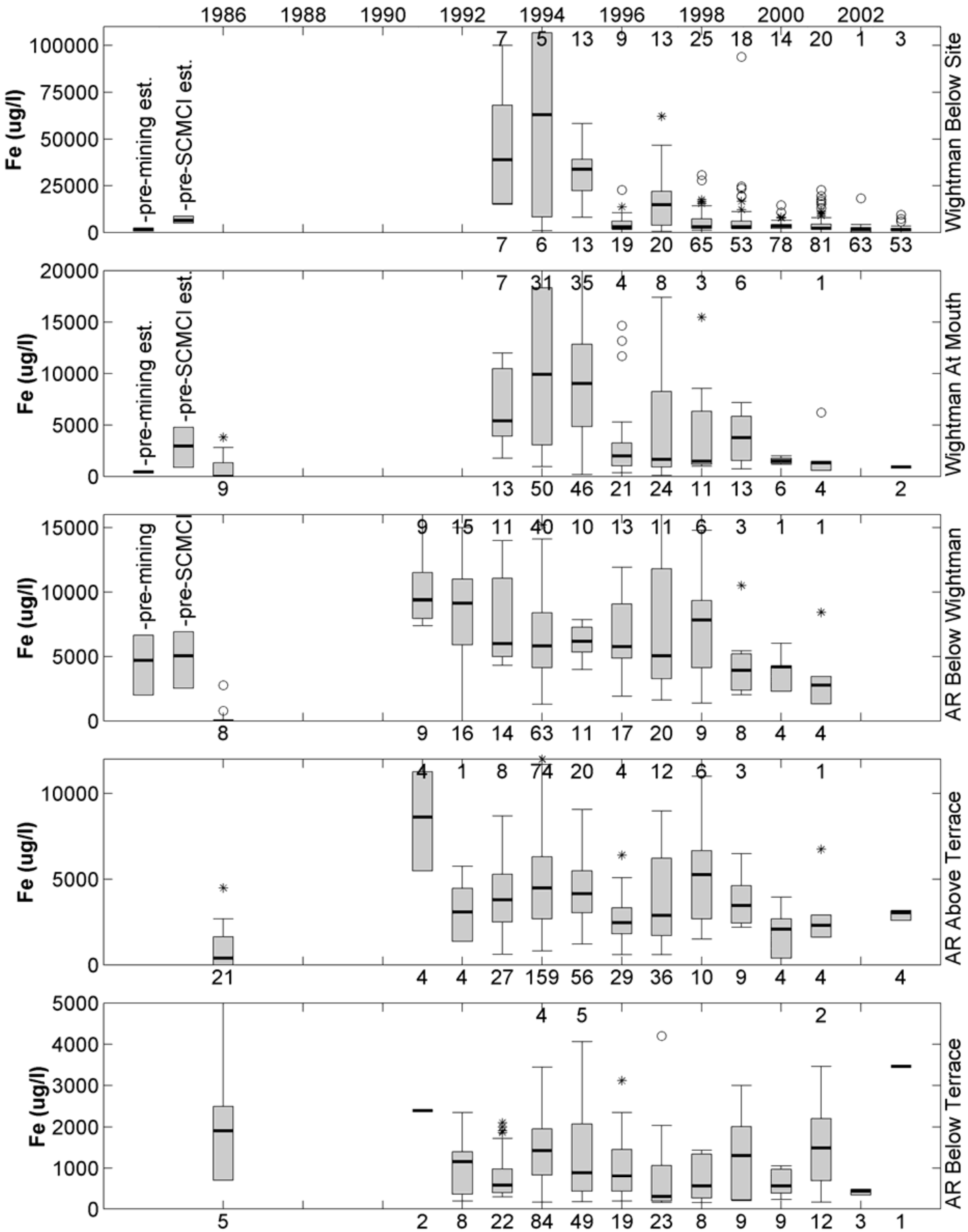


Notes: pre–mining and pre–SCMCI estimates from Medine (1997)

Alamosa River below Wightman includes all data between Jasper Creek and Wightman Fork

Alamosa River above Terrace includes all data between Terrace Reservoir and Jasper Creek

Figure 2–58. Water Quality Downstream of Summitville by Year – Total Iron

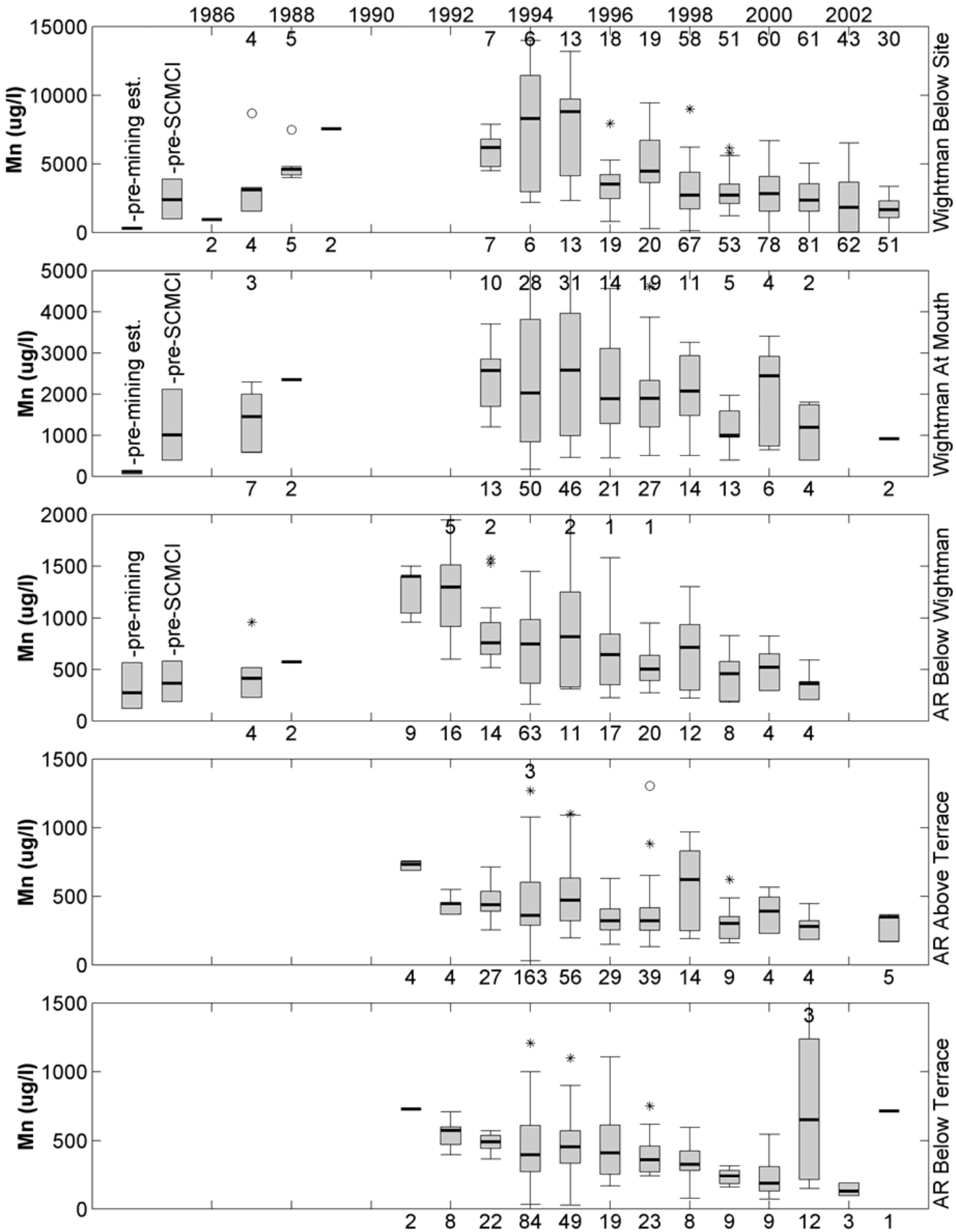


Notes: pre–mining and pre–SCMCI estimates from Medine (1997)

Alamosa River below Wightman includes all data between Jasper Creek and Wightman Fork

Alamosa River above Terrace includes all data between Terrace Reservoir and Jasper Creek

Figure 2–59. Water Quality Downstream of Summitville by Year – Dissolved Manganese

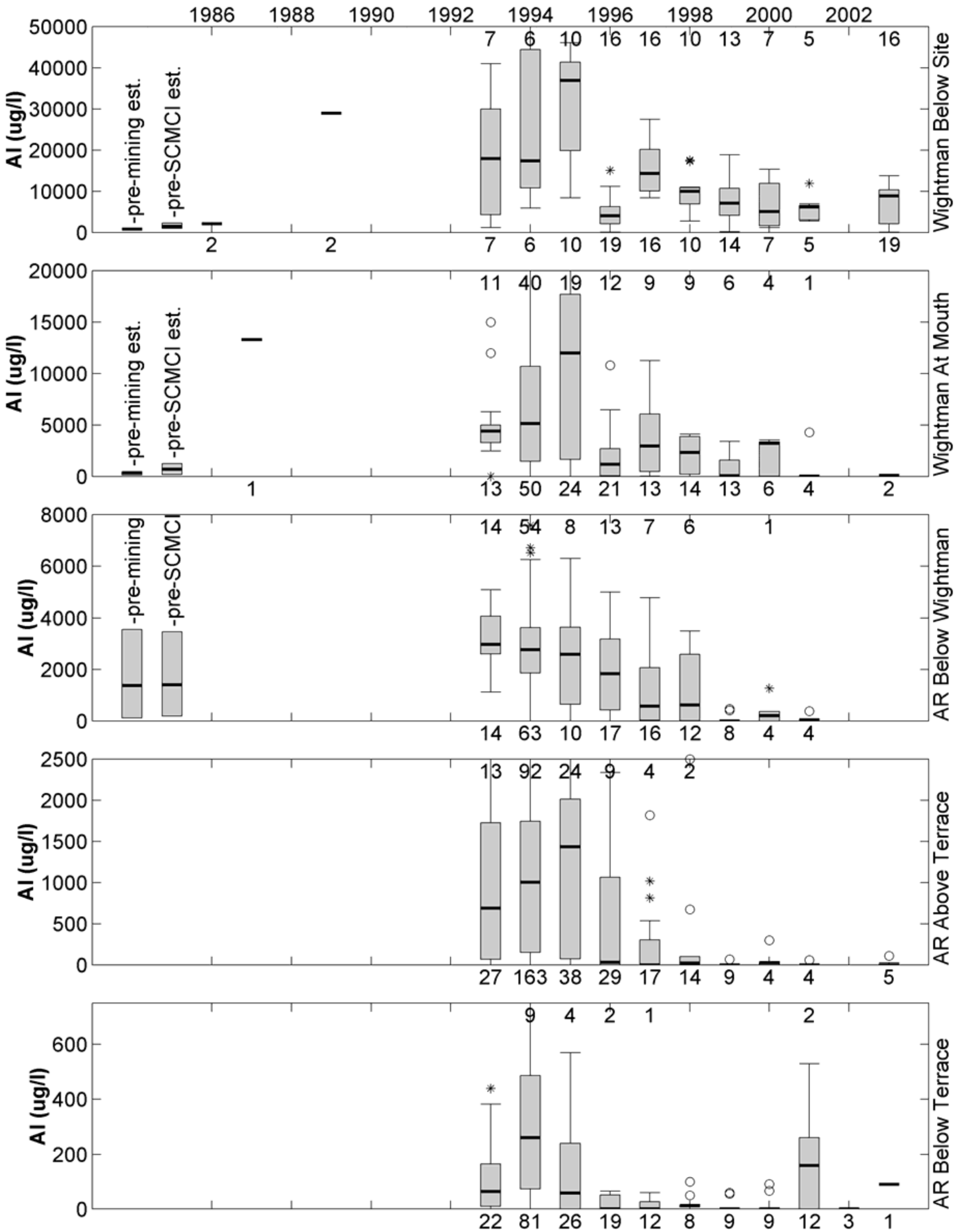


Notes: pre–mining and pre–SCMCI estimates from Medine (1997)

Alamosa River below Wightman includes all data between Jasper Creek and Wightman Fork

Alamosa River above Terrace includes all data between Terrace Reservoir and Jasper Creek

Figure 2–60. Water Quality Downstream of Summitville by Year – Dissolved Aluminum

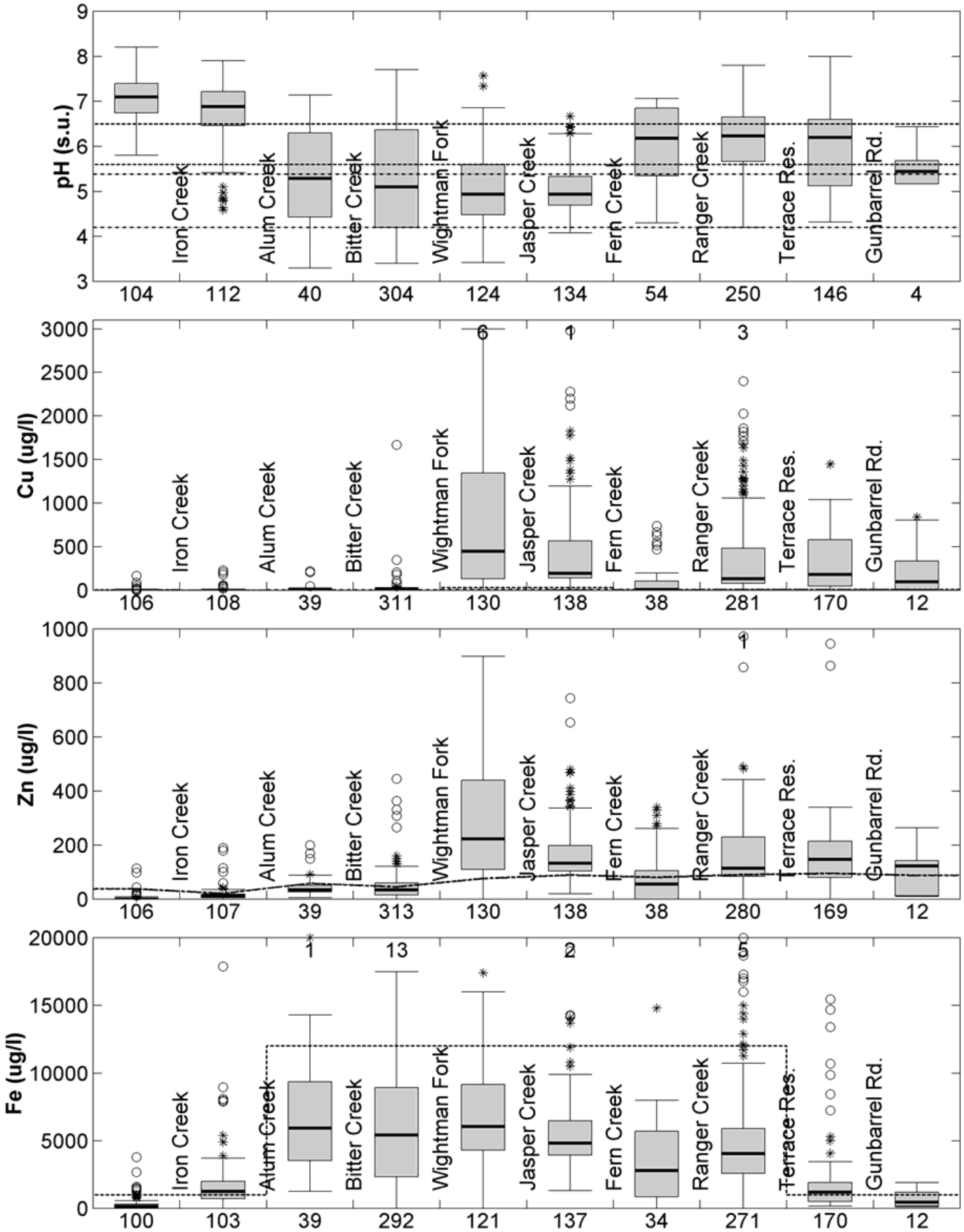


Notes: pre–mining and pre–SCMCI estimates from Medine (1997)

Alamosa River below Wightman includes all data between Jasper Creek and Wightman Fork

Alamosa River above Terrace includes all data between Terrace Reservoir and Jasper Creek

Figure 2–61. Water Quality in Alamosa River Mainstem Following SCMCI; pH, Cu, Zn, Fe



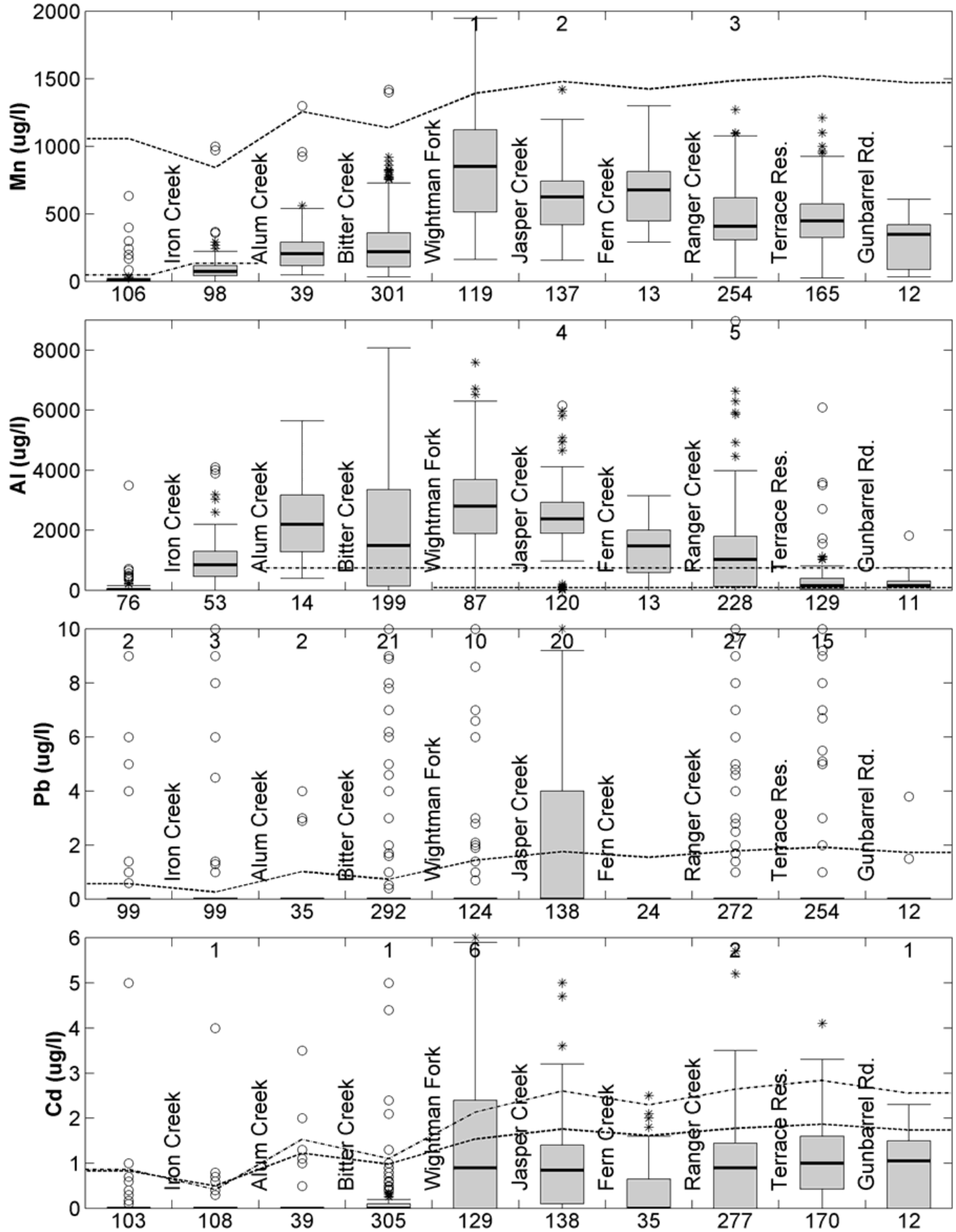
Note: dashed = chronic toxicity standard, dash–dot = acute toxicity standard

for pH: top set = TRVs benthic macroinvertebrates, bottom set = TRVs rainbow trout

metal concentrations are as dissolved except iron which is as total recoverable

Upstream of Wightman Fork – all available data, downstream of Wightman Fork – 1986 to 1995 data

Figure 2–62. Water Quality in Alamosa River Mainstem Following SCMCI; Mn, Al, Pb, Cd



Note: dashed = chronic toxicity standard, dash–dot = acute toxicity standard

metal concentrations are as dissolved

Upstream of Wightman Fork – all available data, downstream of Wightman Fork – 1986 to 1995 data

Water quality generally stabilized after 1998, and a significant improvement of water quality can be observed as a result of remediation activities such as adit plugging, operation of the treatment plant at Summitville, and revegetation of the site by the EPA and CDPHE. **Table 2-16** compares the median of water quality samples taken from 1986 to 1994 with median values from 1998 to 2003. The pre–mining and pre–SCMCI estimates from Medine (1997) are also presented as well as median values from the main stem between Alum Creek and Wightman Fork.

Table 2-16. Comparison of Pre–Summitville, Summitville, and Post–Remediation Water Quality

Parameter	Period	WF Below Site	WF At Mouth	AR Alum To WF	AR Below WF[1]	AR Above Terrace[2]	AR Below Terrace
pH	1986–1994	3.54	5.61	5.19	4.91	6.22	6.13
	1998–2003	4.82	5.32	5.08	5.86	6.49	6.90
Copper	Pre–Mining*	21	9		17	3	
	Pre–SCMCI*	2,143	520		144	12	
	1986–1994	5,442	1,376	10	376	129	236
	1998–2003	980	560	5	65	7	4
Zinc	Pre–Mining*	87	36		50	41	
	Pre–SCMCI*	1,068	450		103	65	
	1986–1994	2,070	704	37	201	108	169
	1998–2003	720	460	20	120	70	37
Iron	Pre–Mining*	1,333	463		4,703		
	Pre–SCMCI*	6,598	2,978		5,065		
	1986–1994	39,000	6,320	5,560	6,040	4,000	1,400
	1998–2003	610	1,550	4,830	4,280	3,170	837
Manganese	Pre–Mining*	295	117		274		
	Pre–SCMCI*	2,385	1,005		367		
	1986–1994	4,950	2,135	210	857	401	445
	1998–2003	2,400	1,600	249	537	337	299
Aluminum	Pre–Mining*	860	363		1,381		
	Pre–SCMCI*	1513	710		1,413		
	1986–1994	18,000	4,645	211	2,800	969	170
	1998–2003	7,650	943	366	50	10	0

Notes: Median value of data set shown, all metal concentrations in µg/l as dissolved except total iron,
*Average of pre–disturbance seasonal estimates from Medine 1997
WF = Wightman Fork, AR = Alamosa River Mainstem
1 = Data from Wightman Fork to Jasper Creek, 2 = Data from Ranger Creek to Terrace Reservoir

The impact of SCMCI activities at Summitville on water quality values is apparent in **Table 2-16**. During this period, median copper concentrations were 376 µg/l in the Alamosa River below Wightman Fork. A significant improvement in water quality can be noted as a result of remediation efforts at Summitville as represented by the 1998 to 2003 time period. Median values for all water quality parameters listed in the table improved. Between 1998 and 2003, the median copper concentration in the Alamosa River below Wightman Fork was 65 µg/l. Median water quality between 1998 and 2003 returned to the levels similar to the pre–SCMCI estimates by Medine 1997. However, it should again be noted that some objections were raised to the methodology used by Medine 1997. Also, years 2002 and 2003 were extremely dry years, and untreated releases from the Summitville site did not occur. The current median data indicates that Wightman Fork continues to produce the majority of copper, zinc, and manganese while sources contributing to the Alamosa River upstream of Wightman Fork now produce the majority of iron and aluminum.

2.4.7 Current Water Quality in Alamosa River Watershed

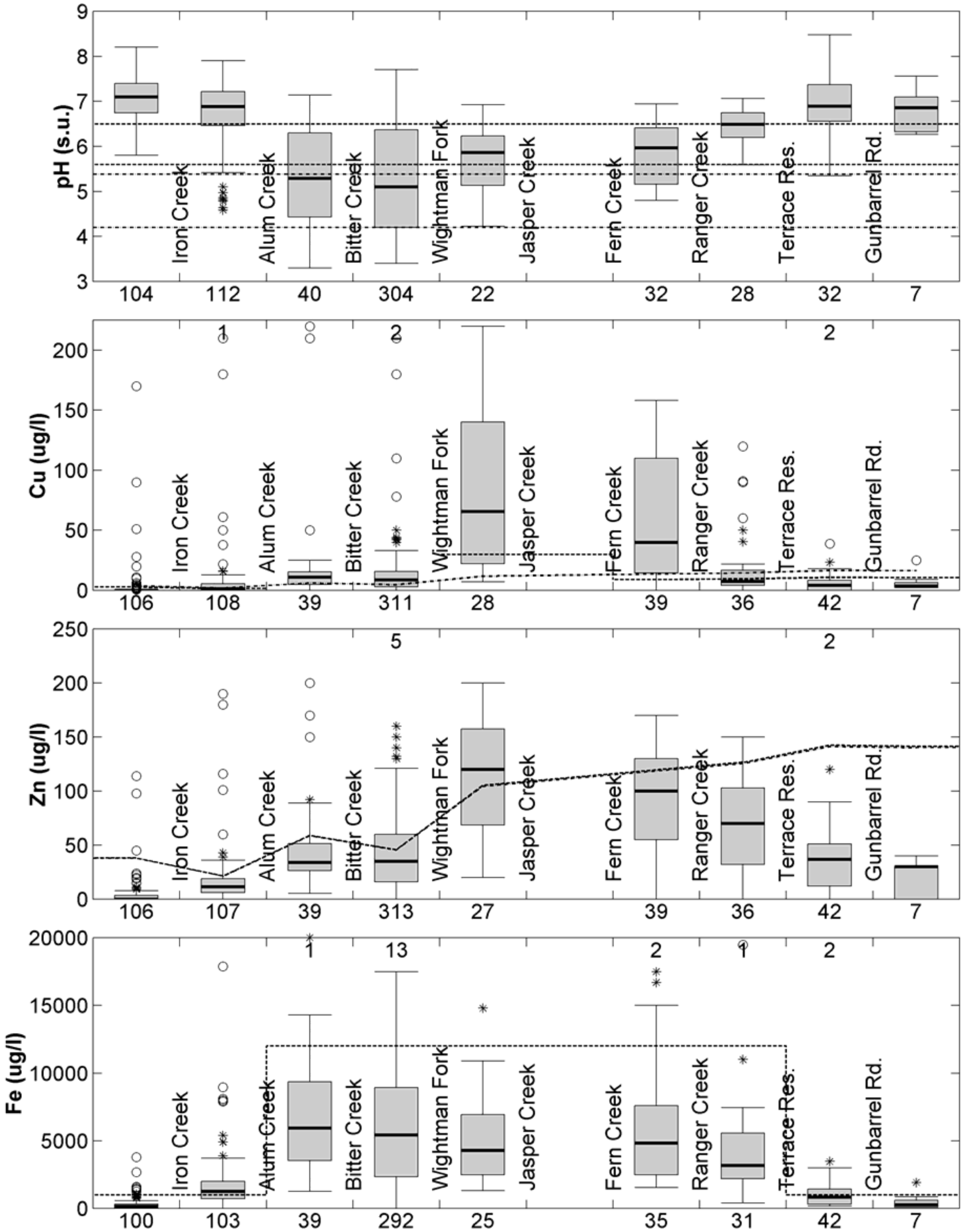
Current Water Quality in Alamosa River Mainstem

Water quality improved significantly following remediation activities at the site, and generally stabilized from 1998 through 2003. This period generally represents current water quality conditions. **Figure 2–63** and **Figure 2–64** characterize current water quality conditions (1998 to 2003) for the same reaches of the Alamosa River mainstem as **Figure 2–61** and **Figure 2–62.** Similarly to these figures, water quality standards and TRVs for pH are also plotted, and all years of available data were used for locations above Wightman Fork.

The pH of the headwaters of the Alamosa River is near neutral. However, pH levels are depressed significantly below Alum Creek. Median pH between Alum Creek and Wightman Fork is below the chronic toxicity level for rainbow trout, and the acute toxicity level for benthic macroinvertebrates. This would indicate that benthic macroinvertebrates are probably severely impacted or even eliminated between Alum Creek and Wightman Fork, and that fish probably cannot survive in this reach. In contrast to the SCMCI time period, water pH now improves in the Alamosa River mainstem below Wightman Fork. However, median pH remains below 6.5 in the Alamosa River mainstem until Ranger Creek. A pH of 6.5 is the CDPHE water quality standard below Wightman Fork as well as the chronic toxicity level for benthic macroinvertebrates.

Although copper levels have improved from the SCMCI time period, concentrations of dissolved copper still increase significantly due to inflow from Wightman Fork and the Summitville area and remain elevated until Ranger Creek and Terrace Reservoir. Zinc, manganese, and cadmium concentrations also continue to rise below Wightman Fork. Levels of lead appear to rise slightly below Wightman Fork, but median lead levels are below detection limits. Aluminum concentrations rise below Iron Creek and more significantly below Alum Creek. Median levels of aluminum exceed chronic and acute toxicity standards between Alum Creek and Wightman Fork. Levels of aluminum decrease significantly below Wightman Fork, but remain elevated until Ranger Creek. Median total iron concentrations rise significantly below Alum Creek, but decrease slightly below Wightman Fork.

Figure 2–63. Current Water Quality in Alamosa River Mainstem; pH, Cu, Zn, Fe



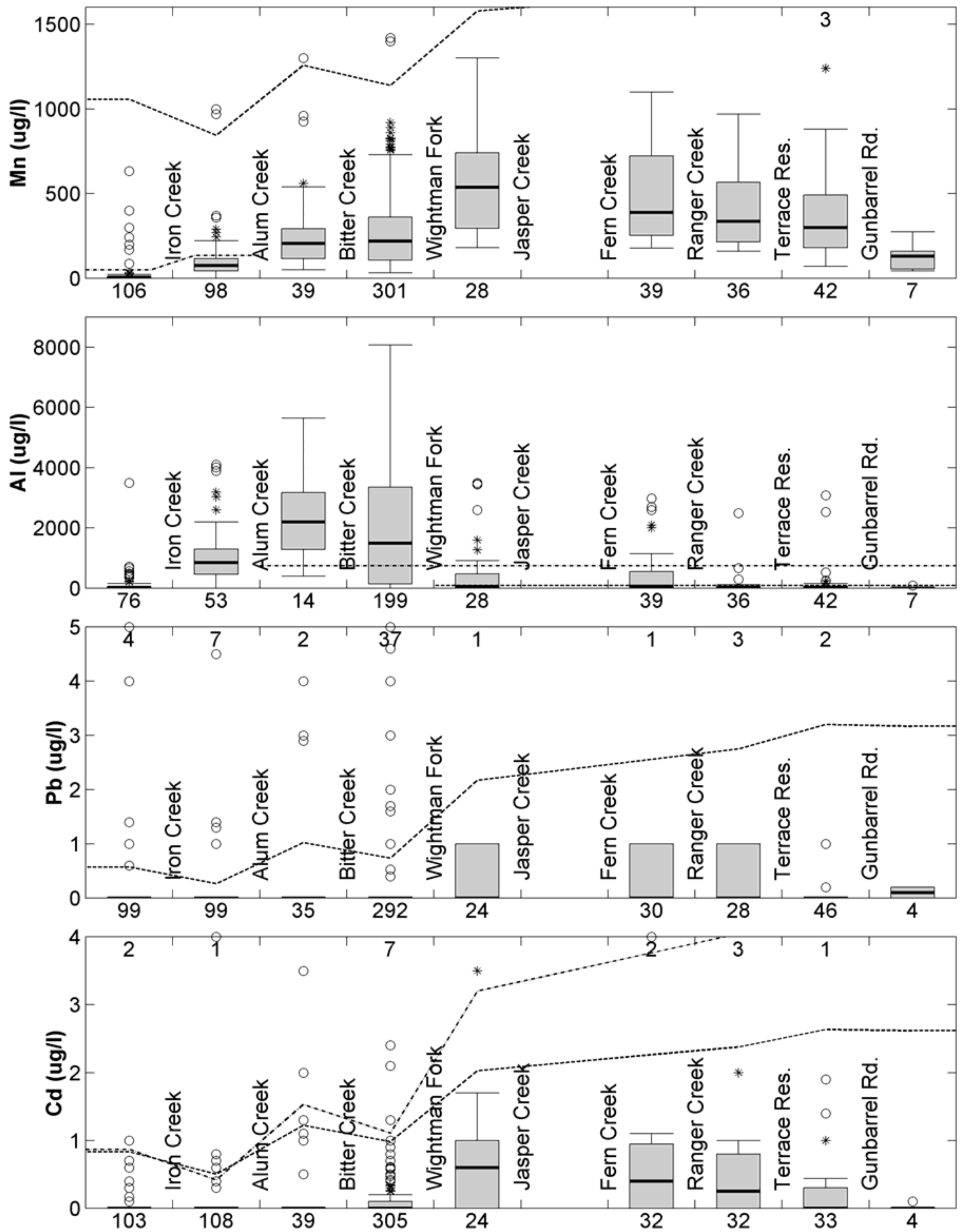
Note: dashed = chronic toxicity standard, dash–dot = acute toxicity standard

for pH: top set = TRVs benthic macroinvertebrates, bottom set = TRVs rainbow trout

metal concentrations are as dissolved except iron which is as total recoverable

Upstream of Wightman Fork – all available data, downstream of Wightman Fork – 1998 to 2003 data

Figure 2-64. Current Water Quality in Alamosa River Mainstem; Mn, Al, Pb, Cd



Note: dashed = chronic toxicity standard, dash–dot = acute toxicity standard

metal concentrations are as dissolved

Upstream of Wightman Fork – all available data, downstream of Wightman Fork – 1998 to 2003 data

Comparison of Current Conditions with Water Quality Standards

As mentioned previously, water quality in the Alamosa River has stabilized since 1998 and data from the 1998 to 2003 time period generally represent current water quality conditions. An average of only about 40 samples is available from each of Segments 3b, 3c, and 3d, and from below Terrace Reservoir (Segments 9 and 10) for this time period. However, the samples are fairly evenly distributed throughout the seasons. **Table 2-17** presents current 85th percentile values for metals concentrations and 15th percentile values for pH as well as applicable CDPHE instream standards by stream segment using 1998 to 2003 data downstream of Wightman Fork. The 85th / 15th percentile values are appropriate for comparison with CDPHE water quality standards and differ from the median values presented in **Table 2-12**. The entire data set was used to calculate statistics for segment 2 and segment 3a, and current data for the mouth of Wightman Fork are also included.

Table 2-17. Current Water Quality Conditions and Instream Standards by WQCC Segment

Segment:	2	3a	WF	3b	3c	3d	9,10
pH	6.58	3.83	4.87	5.01	4.89	5.99	6.17
standard	6.5	3.52–4.73*	2.5	6.5	6.5	6.5	6.5
Copper	2.2	20.0	985.0	171.5	124.0	45.3	11.0
chronic	2.9	–	–	30.0	9.1	9.6	9.0
acute	3.8	4.7	–	12.7	13.6	14.5	13.4
Zinc	10	85	666	170	140	115	57
chronic	38	46	–	113	120	127	118
acute	38	46	–	112	119	126	117
Iron	560	10,996	6,425	9,475	10,290	6,615	2,060
chronic	1,000	12,000	–	12,000	12,000	12,000	1,000
Manganese	17	530	2,935	919	874	695	614
chronic	1,057	1,139	–	1,619	1,658	1,695	1,650
acute	1,912	2,062	–	2,930	3,001	3,068	2,986
Aluminum	219	4,610	3755	2,100	926	100	96
chronic	–	–	–	87*	87	87	87
acute	–	750	–	750	750	750	750
Lead	0.001	3	1	1	1	1	1
chronic	0.57	0.74	–	2.37	2.56	2.75	2.52
acute	14.7	18.9	–	60.7	65.7	70.6	64.6
Cadmium	0.001	0.5	4.9	1.15	1	0.95	0.4
chronic	0.83	0.98	–	2.15	2.26	2.38	2.24
acute	0.87	1.11	–	3.48	3.77	4.05	3.70

Notes: Segments 2 and 3a – all years data, remaining segments – 1998 to 2003 data
85th percentile value of metals concentrations, 15th percentile value for pH, WF = Wightman Fork
All metal concentrations in μg/l as dissolved except total iron; * = varies by season
Chronic standard for zinc, and copper in 3b, exceeds acute standard given TVS and hardness
bold = data exceeds standard

Water quality values that exceed applicable instream standards are indicated in the table with bold text. Water pH becomes very acidic downstream of Alum Creek and exceeds instream standards downstream of Wightman Fork. Although copper concentrations have improved significantly since SCMCI activities at Summitville, copper concentrations are still high in Wightman Fork and exceed instream standards in the Alamosa River downstream of Wightman Fork. Copper is slightly elevated below Alum Creek. Wightman Fork also has a high concentration of zinc, and zinc exceeds instream standards in segments

3a, 3b, and 3c. Total iron exceeds the stricter standard below Terrace Reservoir, but does not exceed current standards upstream of Terrace Reservoir. However, Ortiz and Ferguson (2001) note an acute and chronic toxicological reference value for total iron of 1,000 μg/l for rainbow trout and 320 μg/l for benthic macroinvertebrates. Under these criteria, both rainbow trout and benthic macroinvertebrates would be impacted by total iron concentrations between Alum Creek and Terrace Reservoir. Aluminum concentrations exceed standards below Alum Creek to Fern Creek. Lead exceeds the chronic standard below Alum Creek.

Therefore, although water quality has improved significantly since SCMCI activities at Summitville due to remediation activities, water quality still exceeds pH, copper, zinc, and aluminum standards in Alamosa River segments below Wightman Fork. Concentrations of copper, zinc, aluminum, and lead also exceed the standards established between Alum Creek and Wightman Fork. Concentrations of total iron are also high downstream of Alum Creek, although the established standards are not exceeded except below Terrace Reservoir.

Although some groundwater samples in the Alamosa River watershed have detected arsenic, it has not been identified as a contaminant of concern in surface water. The majority of samples from the Alamosa River mainstem do not detect arsenic, and samples with detectable levels are well below the water quality standards (Medine 1997).

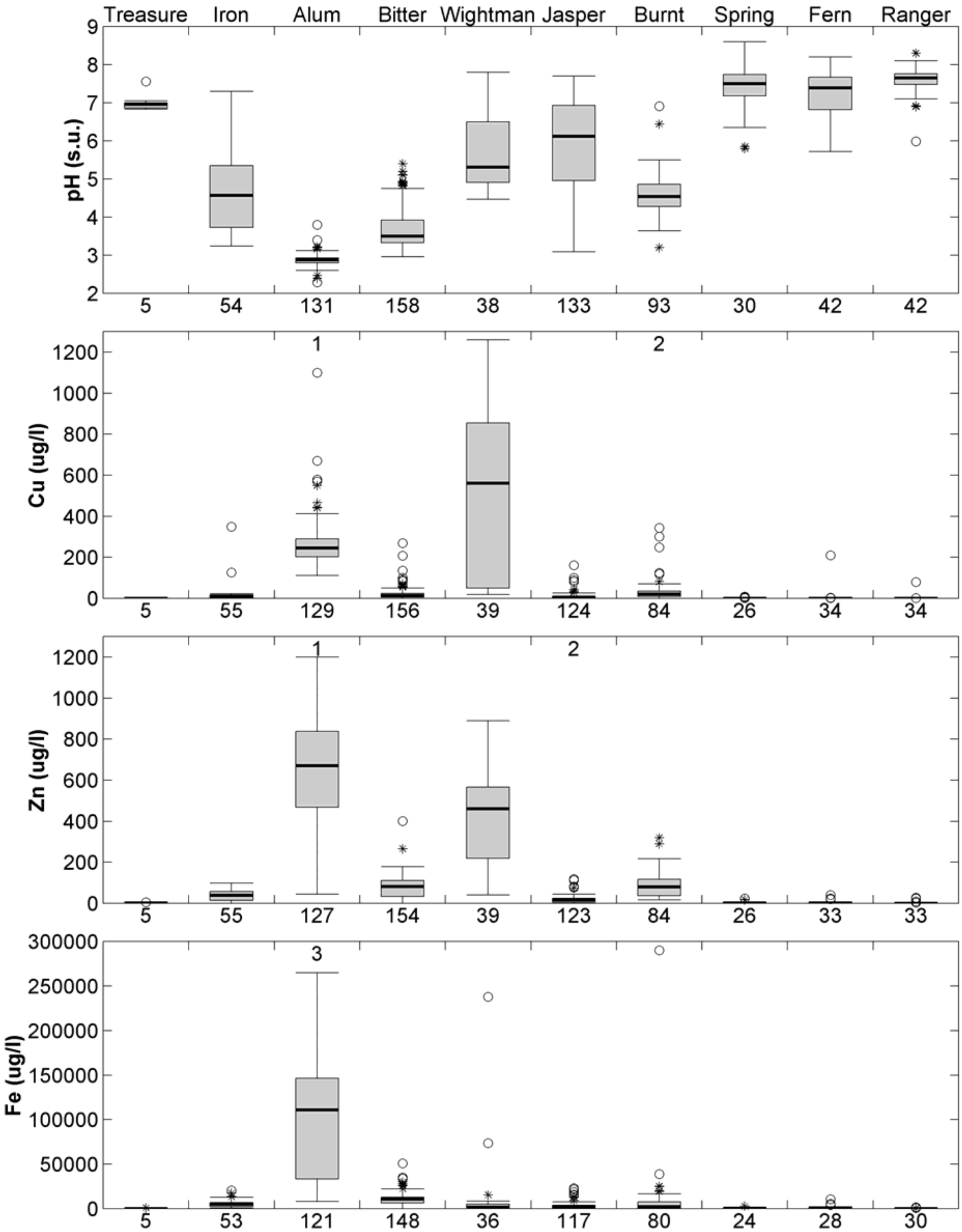
Current Water Quality in Alamosa River Tributaries

The majority of contaminants in the Alamosa River are transported into the river from tributaries that **drain** altered areas. Therefore, it is important to consider the water quality of Alamosa River tributaries. **Figure 2–65** and **Figure 2–66** show summary statistics for water pH and metal concentrations observed at the mouth of major tributaries. For Wightman Fork, only data from 1998 through 2003 was considered in order to generally represent current conditions. All years of available data were considered for other tributaries, as water quality in these tributaries has not changed considerably.

At the headwaters of the Alamosa River, Treasure Creek has a nearly neutral pH with very little variation. However, tributaries draining altered areas have significantly lower pH. The pH of Alum Creek is significantly lower than other tributaries. The median pH in Alum Creek has been 2.88, and a pH as low as 2.29 has been observed. Median pH values in other altered tributaries were 3.50 in Bitter Creek, 4.54 in Burnt Creek, 4.57 in Iron Creek, 5.32 in Wightman Fork, and 6.12 in Jasper Creek. The median pH in Spring Creek, Fern Creek, and Ranger Creek, as well as in Lieutenant Creek and California Gulch (not shown), has been slightly alkaline.

Although copper concentrations have improved significantly due to remediation activities, copper concentrations remain significantly higher in Wightman Fork than in other tributaries. The median copper concentration at the mouth of Wightman Fork during the 1998 through 2003 time period was 560μg/l with a maximum observed concentration of 1,260 μg/l. Copper concentrations in Alum Creek are also elevated with a median value of 246 μg/l, while median copper concentrations in all other tributaries have been below 20μg/l.

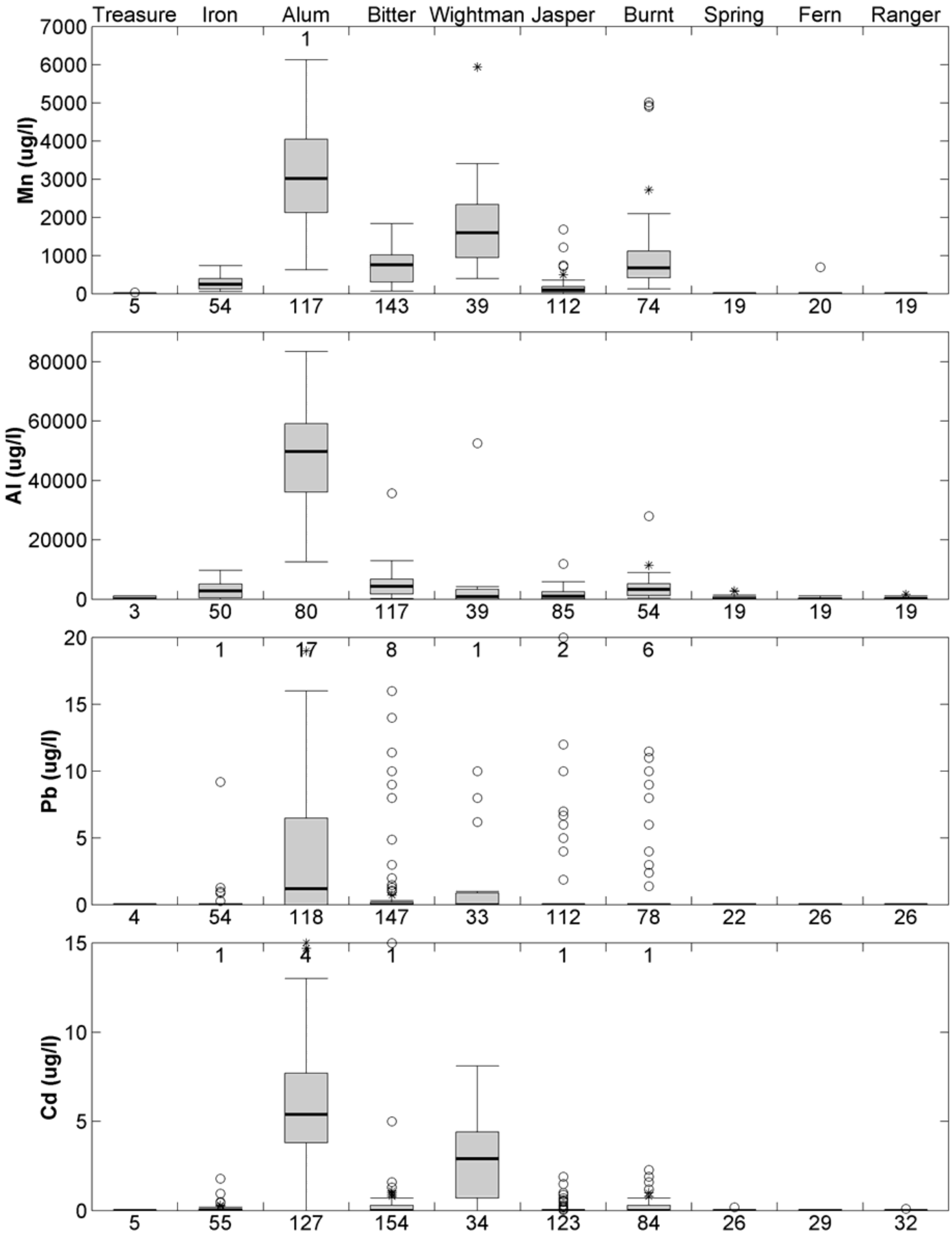
Figure 2–65. Current Water Quality for Alamosa River Tributaries; pH, Cu, Zn, Fe



Note: Metal concentrations are as dissolved except iron which is as total recoverable

Wightman Fork – 1998 through 2003 data, Other tributatires – all available data considered

Figure 2–66. Current Water Quality for Alamosa River Tributaries; Mn, Al, Pb, Cd



Note: metal concentrations are as dissolved

Wightman Fork – 1998 through 2003 data, Other tributatires – all available data considered

Concentrations of aluminum and total iron are significantly higher in Alum Creek than in other tributaries with medians about one order of magnitude higher than in other tributaries. Median aluminum concentrations in Alum Creek have been 49,753 μg/l while then next highest median concentration has been in Bitter Creek at 4,340 μg/l. Median total recoverable iron concentrations in Alum Creek were 111,000 μg/l while current median iron concentrations in Wightman Fork were 1,550 μg/l. Currently, concentrations of zinc, manganese, cadmium, and lead are also highest in Alum Creek, while Wightman Fork has the next highest concentrations of these metals and other tributaries generally have much lower concentrations.

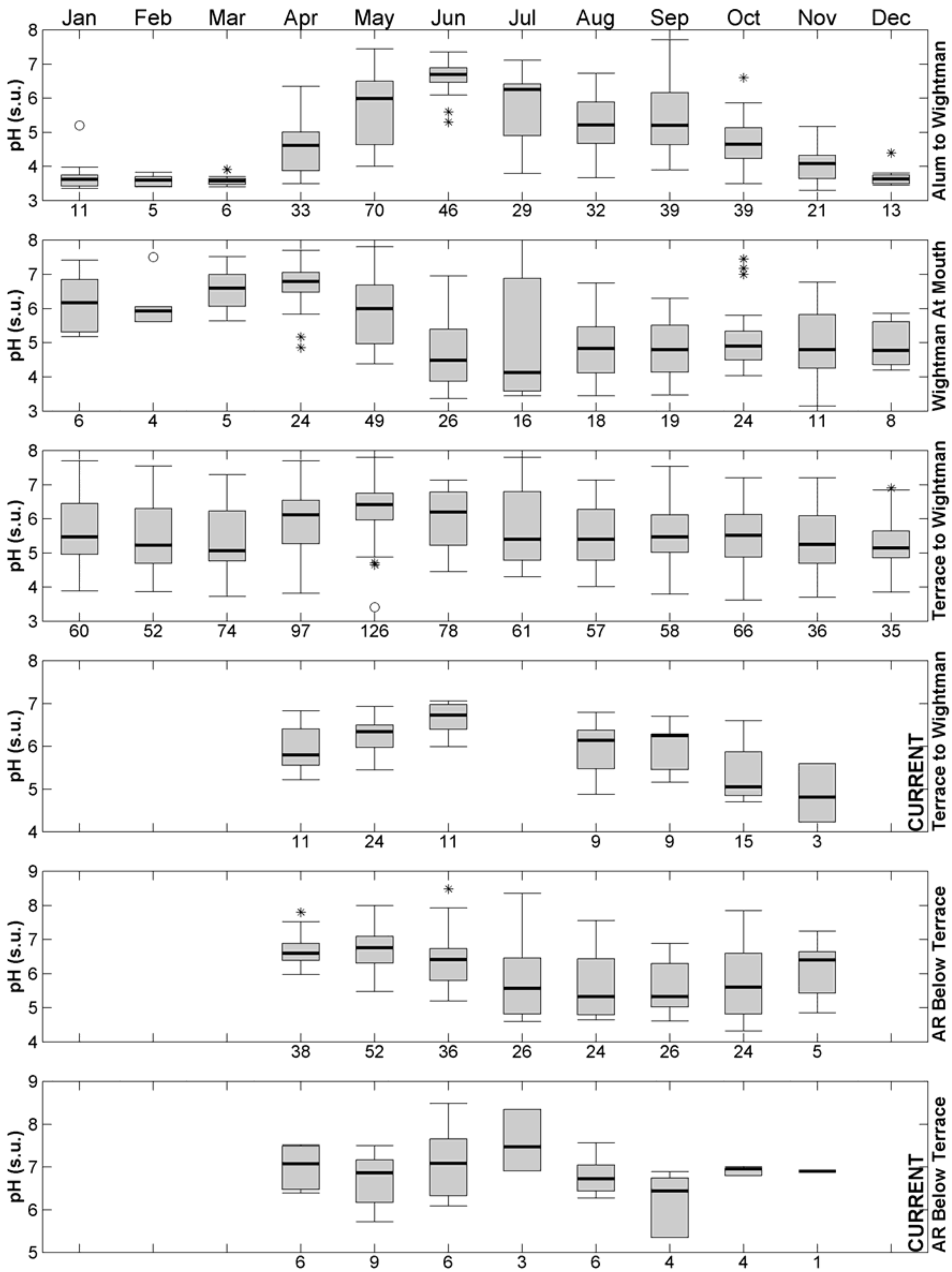
2.4.8 Seasonal Variation in Water Quality

Water quality in the Alamosa River varies considerably by season. Fish and other aquatic organisms must have adequate water quality throughout the year in order to survive and propagate, and an understanding of seasonal changes is important for the consideration of potential remediation alternatives. **Figure 2–67** through **Figure 2–71** show monthly water pH and copper, zinc, iron, and aluminum concentrations for Wightman Fork and reaches of the Alamosa River between Alum Creek, Wightman Fork, Terrace Reservoir, and downstream of Terrace Reservoir. Plots considering data for all years in these reaches are shown in order to have sufficient data sets to understand seasonal patterns. However, plots considering data between 1998 and 2003 are also included in order to understand more recent water quality patterns following remediation activities at Summitville.

The Alamosa River between Alum Creek and Wightman Fork has a very low pH during winter months with a median of about 3.6. The river intersects a portion of the Stunner altered area, and winter flows may consist primarily of base flow out of the Stunner altered area and from the lower elevations of Iron, Alum, and Bitter Creeks. The un–altered tributaries above this reach such as Treasure Creek are at high elevation and would be producing much less winter flow. Alum Creek produces a very large load of iron, and the low pH may also be due, in part, to the formation and precipitation of iron hydroxide, which lowers pH. Water pH increases considerably during summer months due to snowmelt and runoff from the upper unaltered tributaries. Metal concentrations follow a similar pattern with higher concentrations in winter and lower concentrations in the summer.

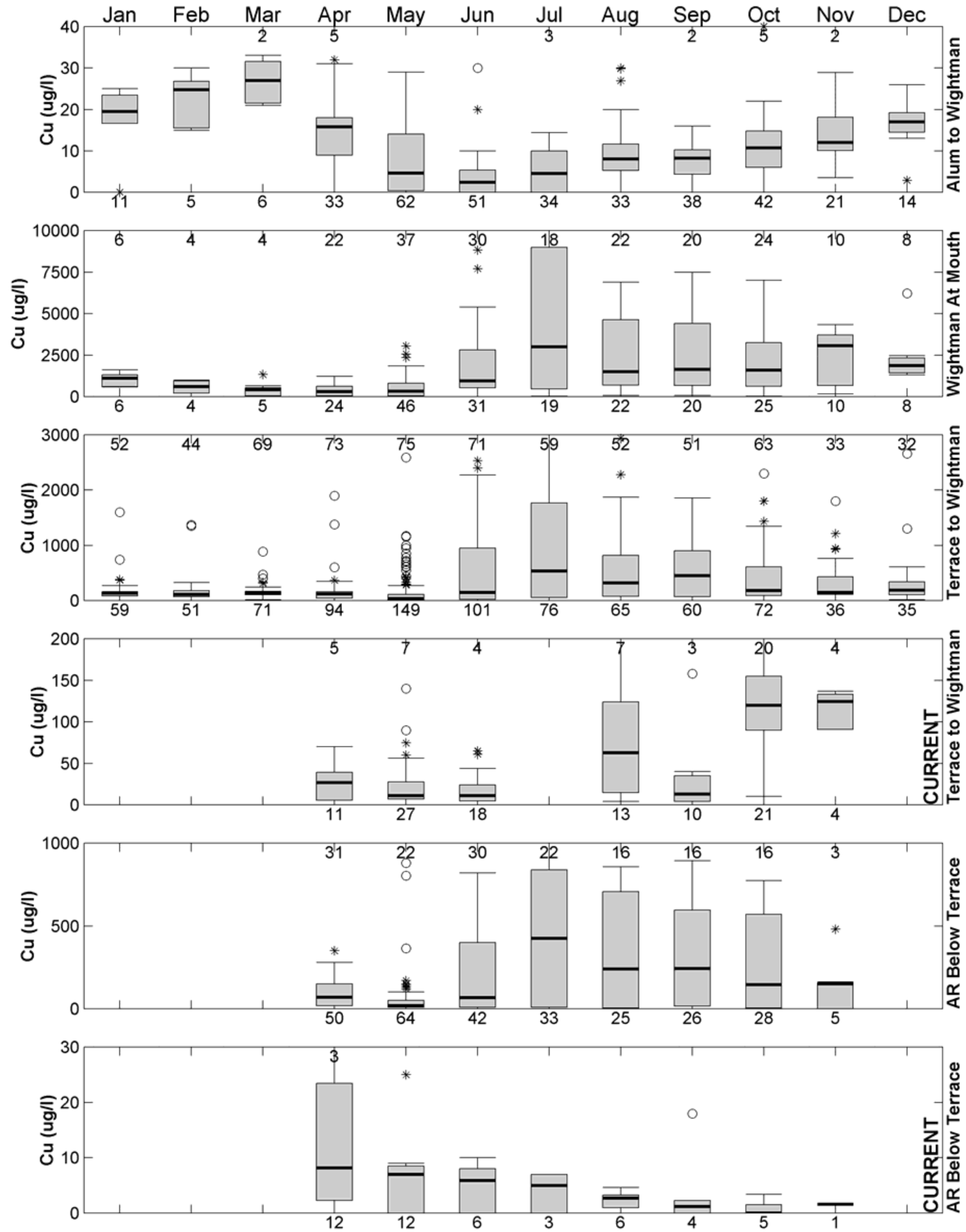
The general characteristics of Wightman Fork are somewhat opposite from the Alamosa River above Wightman Fork. Water pH is relatively high and metals concentrations are relatively low in the winter. In the summer, water pH lowers and metals concentrations become high, particularly during snowmelt. This difference is probably due to the high elevation of the Summitville site. During winter, baseflow from the Summitville altered area may be limited and baseflow may be originating more from lower elevations. The entire data set is influenced by the Reynolds adit prior to plugging when water could rapidly infiltrate through the open pits and out the adit, as well as by untreated SDI releases that have occurred during snowmelt and early summer. There is insufficient current data from the mouth of Wightman Fork to observe a pattern. However, data collected in Wightman Fork below the Summitville site (not shown) indicate that pH decreases and concentrations of copper and zinc now increase throughout the summer and are highest in fall months.

Figure 2–67. Seasonal Water pH for Alamosa River and Tributaries



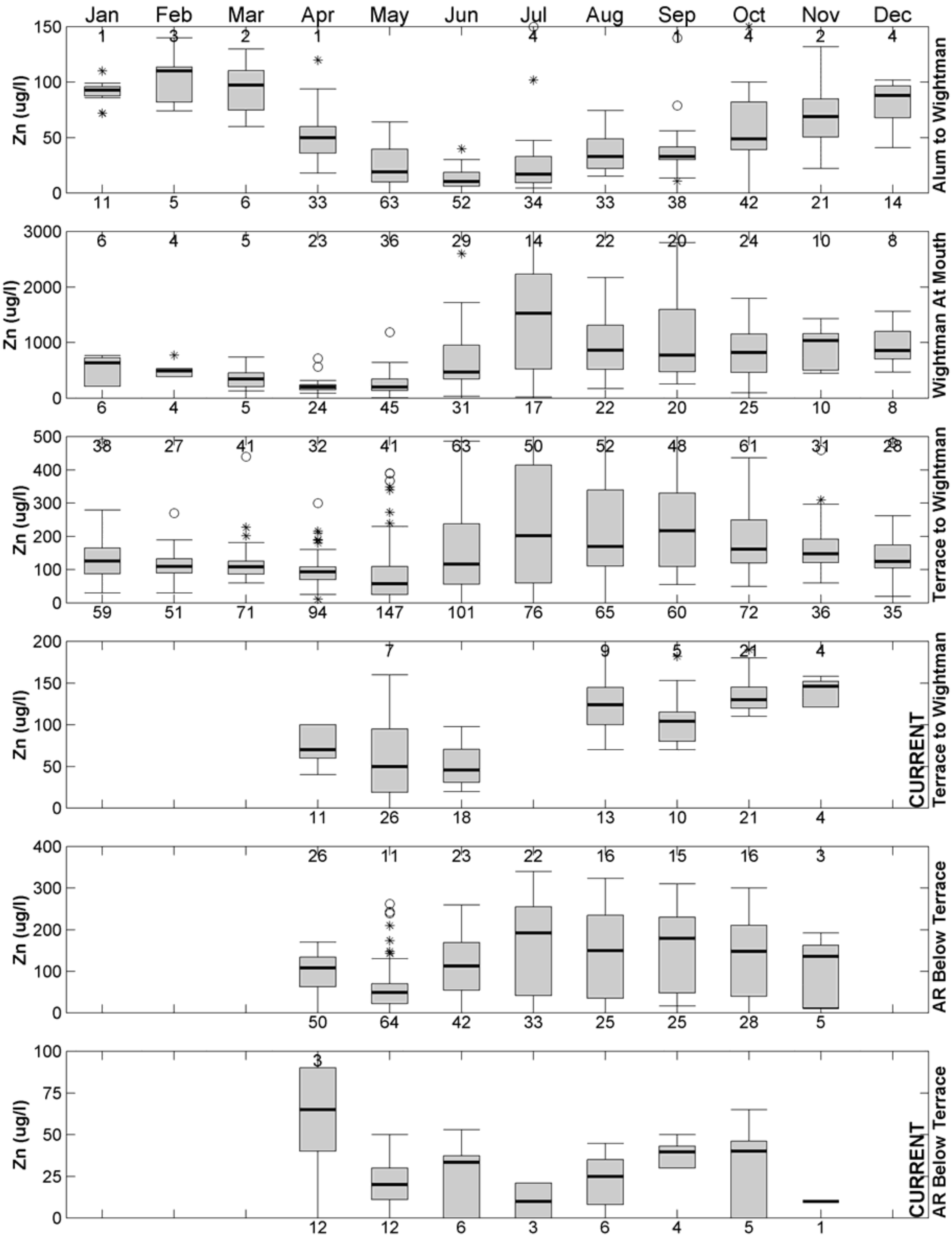
Note: Axes marked current – 1998 to 2003 data, Other axes – all years of data

Figure 2–68. Seasonal Copper Concentrations for Alamosa River and Tributaries



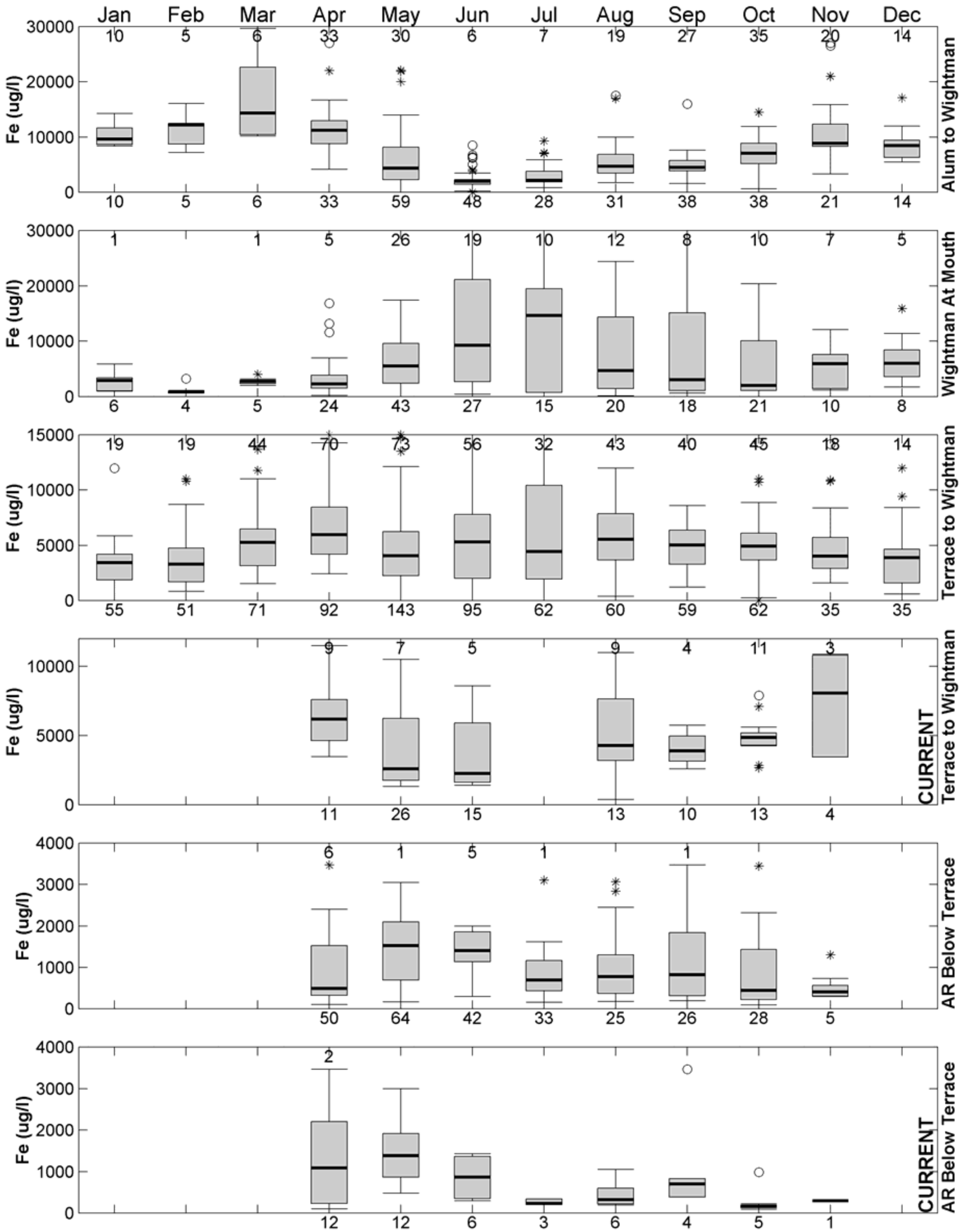
Note: Axes marked current – 1998 to 2003 data, Other axes – all years of data

Figure 2–69. Seasonal Zinc Concentrations for Alamosa River and Tributaries



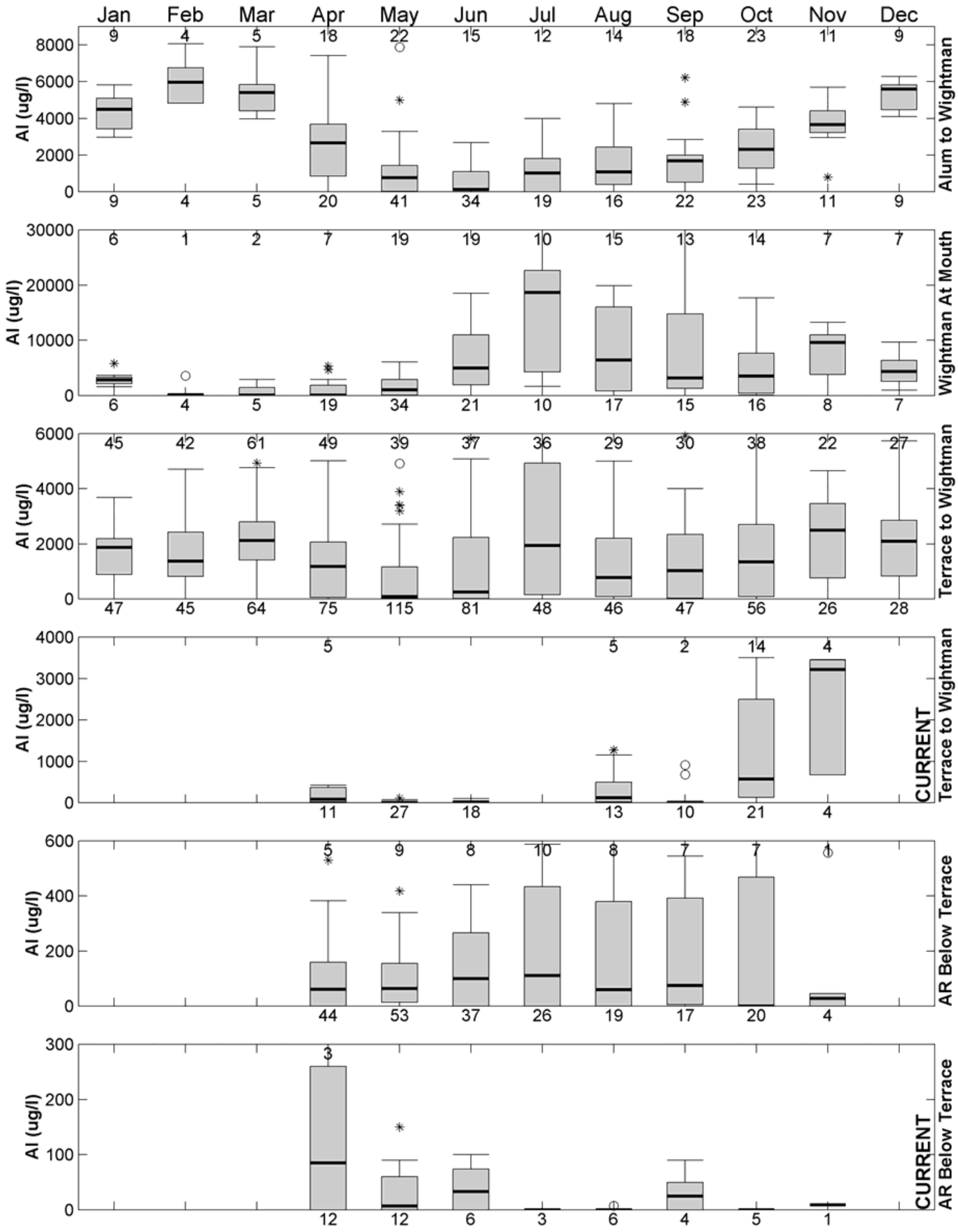
Note: Axes marked current – 1998 to 2003 data, Other axes – all years of data

Figure 2–70. Seasonal Iron Concentrations for Alamosa River and Tributaries



Note: Axes marked current – 1998 to 2003 data, Other axes – all years of data

Figure 2–71. Seasonal Aluminum Concentrations for Alamosa River and Tributaries



Note: Axes marked current – 1998 to 2003 data, Other axes – all years of data

The seasonal water quality between Wightman Fork and Terrace Reservoir is a mixture of the differing characteristics of the upper Alamosa River and Wightman Fork. The entire data set indicated that water pH is lower during the winter due to the upper Alamosa River, but metal concentrations have been higher in the summer due to the contributions of Wightman Fork. Current data indicates that water pH drops and concentrations of copper, zinc, and iron increase significantly in the fall. Copper, zinc, and aluminum have exceeded water quality standards and pH has reached levels that would be toxic to rainbow trout during fall months in current data. In the winter, water pH probably remains low and iron and aluminum concentrations probably remain high due to contributions from the upper watershed although there are no current data from winter months.

Below Terrace Reservoir, water quality patterns have changed following remediation activities at Summitville. In the full data set, water quality was best during spring and worsened during summer and fall months. Currently, metal concentrations have been highest in spring but improve in summer months. Concentrations of zinc have increased somewhat in fall. The high spring concentrations do not appear related to inflowing water quality. The higher spring metal concentrations may be related to resuspension of reservoir sediments due to the high flow rate through the reservoir, the smaller residence time and time for metal particulates to settle due to the higher flow rates, or a flushing of metals that may have dissolved from sediments into the water column during winter months.

2.4.9 Contaminant Loads

In **Section 2.3**, streamflows from ungaged tributaries in the upper Alamosa Watershed were estimated using subwatershed areas and precipitation isohyetals. The estimated tributary streamflows and average metal concentrations were used to estimate the average annual load of metals from the tributaries to the Alamosa River. **Table 2-18** shows estimated average annual contaminant loads from altered tributaries to the Alamosa River. Loads were estimated for Wightman Fork using median concentrations of 1998 to 2003 data while calculations for other tributaries utilized all years of available data. The sum of loads from historic mines other than Summitville and the sum of loads from the five largest NOAMS as estimated by Kirkham et al. 1995 are also included.

Table 2-18. Approximate Annual Loads from Contaminant Sources

Sources:	Copper (lbs/yr)	Zinc (lbs/yr)	Iron (lbs/yr)	Aluminum (lbs/yr)	Manganese (lbs/yr)
Iron Creek	149	772	95,595	55,833	4,784
Alum Creek	1,161	3,162	523,917	234,833	14,254
Bitter Creek	91	587	76,178	31,470	5,533
Wightman Fork	25,298	20,780	70,020	42,599	72,279
Jasper Creek	45	133	12,481	8,175	819
Burnt Creek	104	412	10,364	17,574	3,546
Historic Mines (1)	10	70	18,062	7,060	278
Largest Springs (2)	40	100	13,863	7,422	652

Note: Largest source of contaminant indicated in bold
Metals in dissolved form except total iron
Wightman Fork load calculated using median concentrations of 1998 to 2003 data
Loads for other tributaries calculated using median concentrations for all years of available data
(1) Sum of loads from historic mines other than Summitville estimated by Kirkham et al. 1995
(2) Sum of loads from Upper Iron, Burnt, FR250, Lower Iron, and Bitter Springs estimated by Kirkham et al. 1995

Although remediation efforts have significantly lowered contaminant loads from Wightman Fork, Wightman Fork is still the primary source of copper in the Alamosa River and also produces the largest load of zinc and manganese. Of all contaminant sources estimated in the table, Wightman Fork produces approximately 94% of the copper, 80% of the zinc, and 70% of the manganese. Alum Creek produces the largest loads of iron and aluminum. Alum Creek produces approximately 64% and 58% of the total iron and aluminum, respectively, of sources listed in the table. Iron Creek, Wightman Fork, and Bitter Creek also produce significant loads of these contaminants. Fairly small contaminant loads are produced by Jasper and Burnt Creeks as their average flows are relatively small. Even smaller loads than those calculated are expected to flow directly to the Alamosa River from Burnt Creek as much of the flow of Burnt Creek dissipates into an alluvial fan. However, the contaminants do affect groundwater quality in the Jasper area, and a portion of the load may reach the Alamosa River as groundwater base flow.

Ortiz et al. 2002 examined metal loads in the Alamosa River from mid–1995 through 1997. The USGS collected water quality samples at gage stations and accurately determined loads using gage flow data. Annual loads for 1997 are presented in **Table 2-19**. In 1997, Wightman Fork was the primary source of copper and zinc while sources upstream of Wightman Fork produced slightly higher loads of aluminum and iron. It can be noted that loads of total copper, zinc, iron, and aluminum remained nearly constant or rose slightly in the downstream direction between Wightman Fork and Terrace Reservoir. The concentration of dissolved copper steadily decreased downstream of Wightman Fork and a proportion of copper was apparently changing to a particulate or colloidal form as the total load of copper did not decrease. Zinc remained primarily in dissolved form between Wightman Fork and Castleman Gulch, but a small amount of zinc changed to particulate form between Castleman Gulch and Terrace Reservoir. The majority of iron and aluminum were in particulate form below Wightman Fork. Significant portions of the copper, zinc, iron, and aluminum loads were deposited in Terrace Reservoir.

Table 2-19. Loads of Metals in 1997 in Alamosa River Reaches

Reach	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)
AR above Wightman Fork	0.27	0.54	1.12	1.59	62	395	30	187
Wightman Fork at Mouth	17	19	11.3	11.3	37	217	70	163
AR above Jasper Creek	13.6	22.3	13.2	13.8	90	760	32	412
AR below Castleman Gulch	12	22	13.3	14.3	105	870	28	500
AR above Terrace Reservoir	4	23.2	11.7	15	30	1,140	5	670
AR below Terrace Reservoir	2.9	6.2	9	9.5	6	148	4	84

Note: Data approximated from figures in Ortiz et al. 2002

An understanding of current metal loads is important for consideration of potential remediation alternatives. Current annual loads of dissolved and total metals in the Alamosa River are estimated in **Table 2-1**. Loads are calculated using the median concentrations between 1998 and 2003 (downstream of Wightman Fork) and the average streamflow for the reach as presented in **Section 2.3**. Stream reaches similar to **Table 2-19** are presented, but median concentrations consider all data within a stream reach rather than one location. As seasonal variations are not considered, load estimates should be considered approximate. The third row in the table sums estimated loads from Wightman Fork, Bitter Creek, Alum Creek, and Iron Creek as presented in **Table 2-18**.

Table 2-20. Approximate Current Annual Contaminant Loads in Alamosa River

Reach	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)
AR above Wightman Fork[(1)]	0.4	0.5	1.4	1.8	48.0	259.0	6.3	112.7
Wightman Fork at Mouth	10.8	14.1	10.6	9.9	14.1	35.0	10.0	95.3
Sum of WF and Upper Tributaries[(2)]	13.3		12.7			384.1	184.4	
AR Wightman Fork to Jasper Creek	4.3	10.8	8.1	8.8	62.6	301.0	3.5	196.9
AR Jasper Creek to Castleman Gulch	3.5	9.0	9.0	9.9	75.4	436.2	5.4	248.3
AR Castleman Gulch to Terrace Reservoir	0.8	8.7	7.6	9.5	10.9	362.2	1.0	216.3
AR below Terrace Reservoir	0.3	1.7	3.3	4.4	4.5	90.7	0.0	20.8

Notes: Load estimated using average streamflow and median 1998–2003 concentration except otherwise noted
[(1)]Load estimated using average streamflow and median concentration of all available data
[(2)]Load estimated by summing loads from WF, Iron, Bitter, and Alum Creeks from **Table 2-18**

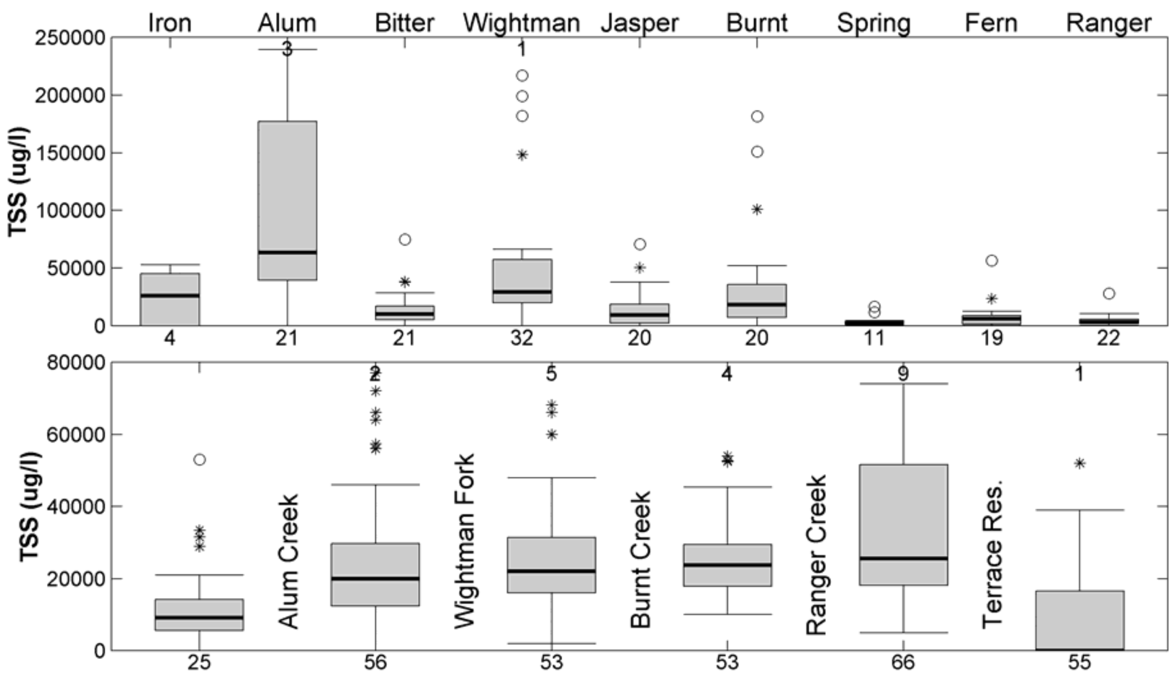
Loads of metals have decreased from 1997 levels and reflect improved water quality due to remediation efforts at the Summitville site. Metals are primarily in dissolved form in altered tributaries. However, a higher portion of copper changes to particulate downstream of Wightman Fork than in 1997, and nearly the entire portion of copper is in particulate form below Castleman Gulch. Similar to 1997, the majority of iron and aluminum remain in particulate form while zinc remains primarily in dissolved form except for some change to particulate form below Castleman Gulch. Significant portions of metal loads are still being deposited in Terrace Reservoir.

2.4.10 Suspended Sediments

Clay minerals in hydrothermally altered areas are easily eroded and suspended in surface waters. The water of the Alamosa River is often observed to be turbid. However, levels of suspended sediments rise exponentially during spring snow melt and precipitation effects. Many accounts describe waters becoming extremely turbid following rainstorms. The local water commissioner noted that water often turns different colors depending on the locations of thunderstorms in the watershed (Joe McCann, oral commun. 2004). Suspended sediments can coat gills and literally suffocate fish and cover spawning gravels or eggs. Fine sediments in the Alamosa River may also have the potential to oxidize and lower pH or release heavy metals. Some turbidity may also be related to the high load of metals in particulate or colloidal forms.

Unfortunately, very little quantitative data is available describing turbidity or suspended sediments concentrations and loads. Levels of total suspended solids have been reported in a limited number of water quality samples. Box plots describing suspended solid data for the Alamosa River mainstem and tributaries are presented in **Figure 2–72**. In the Alamosa mainstem, suspended solids concentrations increase below Alum Creek and appear to rise again between Ranger Creek and Terrace Reservoir. A major portion of the load of suspended solids is deposited in Terrace Reservoir. However, relatively high levels of suspended solids have been observed below Terrace Reservoir. Alum Creek consistently has a much higher concentration of suspended solids than other tributaries, although Wightman Fork, Iron Creek, and Burnt Creek also have relatively high concentrations. Few of the water samples were taken during storm events. It is anticipated that levels of suspended sediments produced during storm events may be a significant risk to fish populations restored to the Alamosa River. Additional study and understanding of suspended sediment loads in the Alamosa River would be useful for consideration of remediation alternatives in the Alamosa River.

Figure 2–72. Concentrations of Total Suspended Solids in Mainstem and Tributaries



Note: Data considered from entire data set in Alamosa River mainstem (bottom) and tributaries (top)

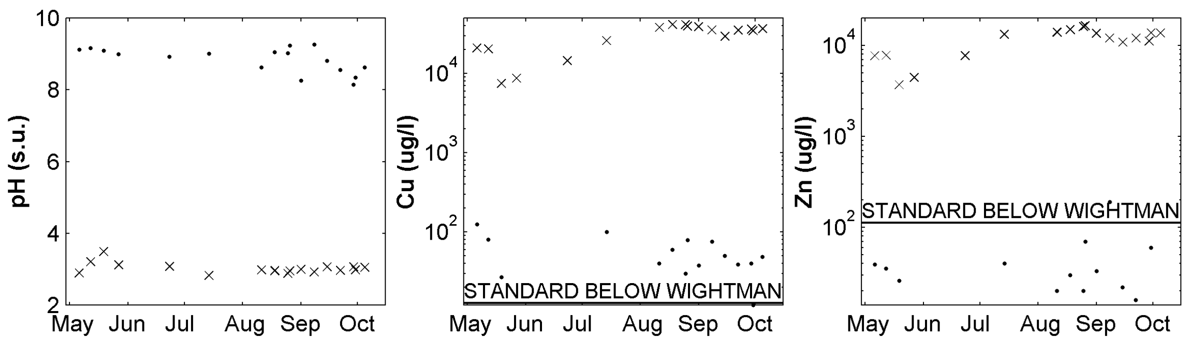
2.4.11 Expected Future Trends

Water quality in the Alamosa River upstream of Wightman Fork is primarily determined by natural conditions and processes, and should not change significantly from current conditions. Water pH is impacted significantly by Alum Creek and other altered tributaries, and waters will likely remain acidic downstream of Alum Creek to Terrace Reservoir in the absence of remediation activities. High aluminum and iron concentrations are also caused primarily by tributaries upstream of Wightman Fork and will likely remain high into the future.

Dissolved copper and zinc still exceed water quality standards in many reaches of the Alamosa River and probably would impact restored aquatic species. Wightman Fork and the Summitville area are the primary source of copper and zinc in the Alamosa River, and concentrations during much of the year are dependent on the efficiency of the treatment plant at Summitville. **Figure 2–73** shows the pH, copper concentrations, and zinc concentrations of water treatment plant influent and effluent observed during year 2003. During 2003, the pH of influent to the water treatment plant averaged 3.0 while the pH of effluent averaged 8.8. The treatment plant reduced copper concentrations from an average of 30,000 μg/l to 56 μg/l and reduced zinc concentrations from an average of 11,400 μg/l to 46 μg/l. Therefore, the current treatment plant is removing a tremendous load of both copper and zinc from the

Alamosa River. However, the plant is not able to remove copper to the level of the current copper standard in the Alamosa River (about 12.7 μg/l).

Figure 2–73. Year 2003 Water Treatment Plant Influent and Effluent Water Quality



Note: x = treatment plant influent, · = treatment plant effluent; y–axis displayed using logarithmic scale

CDPHE and the EPA have recognized that copper should be treated to the level of the instream standards in the Alamosa River and have proposed building a new treatment plant to meet this treatment goal. Untreated releases from the site can also be expected to continue unless the capacity of the SDI and the current treatment plant are increased. CDPHE has been preparing designs for a new treatment plant, and final design and construction bid documents should be completed by fall of 2004, although it will not go out to bid if it is not funded (Buckingham, 2004). The new treatment plant is estimated to cost on the order of $15.6 million, and it is also proposed to spend about $10 million to enlarge the SDI. However, funding for the project in the near future is considered highly unlikely given the current political environment and funding levels in the EPA Superfund program (Hanley, 2004). The project would most likely require a direct appropriation from the state or U.S. legislature given the current political environment. Therefore, contaminant levels from the Summitville site are not expected to improve considerably from current levels unless a new treatment plant is constructed.

2.4.12 Summary of Water Quality Issues

Hydrothermally altered areas naturally create water quality conditions with low pH and high metal concentrations in some areas of the Alamosa River watershed. Historic mining created additional sources of contamination. Open pit and cyanide heap leach operations at Summitville exposed tremendous amounts of sulfide minerals to oxidation which severely impacted downstream water quality and killed fish populations throughout the Alamosa River below Wightman Fork.

Water quality in the Alamosa River downstream of Wightman Fork has improved significantly in recent years due to remediation efforts at Summitville. However, water quality below Wightman Fork continues to exceed pH, copper, zinc, and aluminum standards. Iron concentrations are also high in comparison to toxicological reference values for benthic macroinvertebrates and fish. Wightman Fork continues to produce the large majority of copper and zinc to the Alamosa River, while Alum Creek and other sources upstream of Wightman Fork produce the majority of iron and aluminum. Currently, concentrations of copper and zinc between Wightman Fork and Terrace Reservoir appear to be poorest in late summer and fall while levels of pH, iron, and aluminum are probably poorest in fall and winter. In order to restore water quality below Wightman Fork to levels that could support a long–term fishery, a treatment mechanism may be needed to raise pH and remove portions of the copper, iron, aluminum, and zinc loads.