Total Maximum Daily Load Assessment
Arkansas River/Lake Creek/Chalk Creek/Evans Gulch
Lake/Chaffee County, Colorado

Colorado Department of Public Health and Environment
Water Quality Control Division

June, 2009

TMDL Summary	
Waterbody Description / WBID	Mainstem of the Arkansas River from a point immediately above California Gulch to a point immediately above the confluence with Lake Creek (COARUA2b, COARUA2c)/Mainstem of the Arkansas River from a point immediately above the confluence with Lake Creek to the inlet to Pueblo Reservoir (COARUA03)/All tributaries to the Arkansas River, including wetlands, lakes, and reservoirs, from the source to immediately below the confluence with Browns Creek, except for specific listings in segments 6 through 12b (COARUA05)/Mainstem of Evans Gulch from the source to the confluence with the Arkansas River (COARUA07)/Mainstem of the South Fork of Lake Creek, including all tributaries, wetlands, lakes and reservoirs, from the source to the confluence with Lake Creek (COARUA11)/Mainstem of Chalk Creek from the source to the confluence with the Arkansas River (COARUA12a).
Pollutants Addressed	Dissolved Cadmium, Dissolved Copper, Dissolved Aluminum, Dissolved Lead, Dissolved Zinc, and pH.
Relevant Portion of Segment (as applicable)	Mainstem of the Arkansas River from a point immediately above California Gulch to a point immediately above the confluence with Lake Creek, Segments 2b and 2c; mainstem of the Arkansas River from immediately above the confluence with Lake Creek to the inlet to Pueblo Reservoir, Segment 3; Halfmoon Creek in Segment 5; mainstem Evans Gulch, Segment 7; mainstem of the South Fork of Lake Creek, including all tributaries, wetlands, lakes and reservoirs, from the source to the confluence with Lake Creek, Segment 11; and the mainstem of Chalk Creek from the source to the confluence with the Arkansas River, Segment 12a.
Use Classifications / Designation	Segments 2b and 2c: Aquatic Life Cold 1, Recreation E, Agriculture; Segments 3, 5, and 7: Aquatic Life Cold 1, Recreation E, Water Supply, Agriculture; Segment 11: Aquatic Life Cold 1, Recreation E, Agriculture; Segment 12a: Aquatic Life Cold 1, Recreation E, Water Supply

Water Quality Targets (for dissolved fraction of metals)	**Segment 2b**	**Chronic**	**Acute**
	Cd-D	(1.101672-(ln(hard)*0.041838)) * (e((0.7998 * (ln(hard)))-3.1725))	(1.136672-(ln(hard) * 0.041838)) * (e((0.9151*(ln(hard)))-3.6236))
	Zn-D	0.986*(e((0.8537*(ln(hard)))+2.0469))	0.978*(e((0.8537*(ln(hard)))+2.2178))
	Segment 2c	**Chronic**	**Acute**
	Cd-D	(1.101672-(ln(hard)*0.041838)) * (e((0.7998 * (ln(hard)))-3.1725))	(1.136672-(ln(hard) * 0.041838)) * (e((0.9151*(ln(hard)))-3.6236))
	Zn-D	0.986*(e((0.8537*(ln(hard)))+2.0469))	0.978*(e((0.8537*(ln(hard)))+2.2178))
	Segment 3	**Chronic**	**Acute**
	Cd-D	TVS	TVS
	Zn-D	TVS	TVS
	Segment 5	**Chronic**	**Acute**
	Pb-D	TVS	TVS
	Cd-D	TVS	TVS
	Segment 7	**Chronic**	**Acute**
	Zn-D	TVS	TVS
	Segment 11	**Chronic**	**Acute**
	pH	6.5-9.0	6.5-9.0
	Al-D	--	750
	Cd-D	TVS	TVS
	Cu-D	--	TVS
	Zn-D	TVS	TVS
	Segment 12a	**Chronic**	**Acute**
	Zn-D	TVS	TVS
	Pb-D	TVS	TVS
TMDL Goal	Attainment of Aquatic Life Use Classification		

EXECUTIVE SUMMARY

The Upper Arkansas River watershed spans both Lake and Chaffee Counties, Colorado, once home to one of the richest mining districts in the world (Figure 1). The mainstem of the Arkansas River from a point immediately above California Gulch to immediately above the confluence with Lake Creek, Segments 2b, and 2c (Cd, Zn); the mainstem of the Arkansas River from a point immediately above the confluence with Lake Creek to the confluence with Badger Creek, Segment 3 (Cd, Zn); Halfmoon Creek in Segment 5 (Cd, Pb); Evans Gulch from its source to the Arkansas River, Segment 7 (Zn); Sayres Gulch in Segment 11 (pH, Al, Cd, Cu, Zn); and the mainstem of Chalk Creek from the source to the confluence with the Arkansas River, Segment 12a (Pb, Zn), appear on the Colorado 2008 303(d) list for non-attainment of dissolved metals standards (Table 1) (WQCC 2006a). These metals impair the Aquatic Life Cold 1 use classification. The high concentration of metals is primarily the result of over 140 years of mining activity in the watershed from the 1860's through 1999. The last active mine closed in 1999.

Segment #	Segment Description	Portion	1998 303(d) Listed Contaminants

Segment 2b	Mainstem of the Arkansas River from a point immediately above California Gulch to a point immediately above the confluence with Lake Fork.	mainstem	Cd, Zn
Segment 2c	Mainstem of the Arkansas River from a point immediately above the confluence with the Lake Fork to a point immediately above the confluence with Lake Creek.	mainstem	Zn (2006: Cd)
Segment 3	Mainstem of the Arkansas River from a point immediately above the confluence with Lake Creek to the inlet to Pueblo Reservoir	all	Pb, Zn (2006: Pb delisted; 2008: Cd))
Segment 5	All tributaries to the Arkansas River, including wetlands, lakes, and reservoirs, from the source to immediately below the confluence with Browns Creek, except for specific listings in segments 6 through 12.	Halfmoon Creek	Pb (2006) Cd (2008)
Segment 7	Mainstem of Evans Gulch from the source to the confluence with the Arkansas River	all	Zn
Segment 11	Mainstem of South Fork of Lake Creek, including all tributaries, wetlands, lakes and reservoirs, from the source to the confluence with Lake Creek.	all	Al, Cu (2006: pH, Zn) (2008: Cd)
Segment 12a	Mainstem of Chalk Creek from the source to the confluence with the Arkansas River.	mainstem below Mary Murphy Mine	Zn (2008: Pb)

Table 1. Segments within the Arkansas River watershed that appear on the 1998 303(d), 2006 303(d), and 2008 303(d) Lists of impaired waters for excessive heavy metals.

The Arkansas River and surrounding tributaries contain a number of mine-site related features. Due to sizeable quantities of mine waste rock and the slow biogeochemical process of acid rock discharge, this pollution can continue to flow long after the mining ends. California Gulch (COARUA06) was placed on the National Priorities List (NPL) for clean-up under Superfund in 1983 because of concerns about the impact of heavy metals on the Arkansas River. Reduction of metals in the upper segments of the Arkansas River (COARUA02b and COARUA02c) will be accomplished mainly through Superfund/CERCLA activities and treatment of abandoned mine drainage in the basin. Water quality in these listed segments will be affected by the ongoing Superfund remediation efforts at California Gulch.

I. INTRODUCTION

Section 303(d) of the federal Clean Water Act requires States to periodically submit to the U. S. Environmental Protection Agency (EPA) a list of water bodies that are water-quality impaired. A water-quality impaired segment does not meet the standards for its assigned use classification. This list of impaired water bodies is referred to as the “303(d) List”. The List is adopted by the Water Quality Control Commission (WQCC) as Regulation No. 93.

For waterbodies and streams on the 303(d) list a Total Maximum Daily Load (TMDL) is used to determine the maximum amount of a pollutant that a water body may receive and still maintain water quality standards. The TMDL is the sum of the Waste Load Allocation (WLA), which is the load from permitted and non-permitted point source discharges, Load Allocation (LA) which is the load attributed to natural background and/or non-point sources, and a Margin of Safety (MOS) (Equation 1).

(Equation 1) $$TMDL=WLA+LA+MOS$$

The Upper Arkansas River watershed is encompassed by Lake and Chaffee Counties, Colorado, once home to one of the richest mining districts in the world (Figure 1). The mainstem of the Arkansas River from a point immediately above California Gulch to the inlet to Pueblo Reservoir (Segments 2b, 2c, and 3), Evan's Gulch from its source to the Arkansas River in Segment 7, Sayres Gulch in Segment 11, and the mainstem of Chalk Creek from the source to the confluence with the Arkansas River in Segment 12a, appear on the Colorado 1998 303(d) List for non-attainment of pH, dissolved cadmium, zinc, aluminum, lead, and copper standards (Table 1) (WQCC, 2006b). Several revisions have been made to the 303(d) List since 1998 (every two years; i.e. 2000, 2002, 2004, 2006, and 2008). On the 2008 303(d) List, Segment 2c is also listed for dissolved cadmium, Segment 3 was de-listed for dissolved lead and listed for cadmium in 2008, Segment 5 was listed for lead in 2006 and cadmium in 2008, in Segment 11, pH and zinc were added in 2006 along with cadmium in 2008, and in Segment 12a, lead was added in 2008. As demonstrated by the delisting for lead in Segment 3, a segment or pollutant may be removed from the List if the applicable standard is attained, if implementation of clean up activities via an alternate means will result in attainment of standards, if the original listing decision is shown to be in error, or if the standards have been changed as the result of a Use Attainability Analysis (UAA).

II. GEOGRAPHICAL EXTENT

The Arkansas River drainage basin (Figure 1) lies south and west of the town of Leadville. The listed segments on this 303(d) listed portion of the upper Arkansas account for 163 miles of the 1,450 mile length of river. The upper Arkansas is flanked on the west by Mount Elbert, the highest peak in Colorado with an elevation of 14,433 feet and flows just east of the Sawatch mountain range. Many tributaries flow into the Arkansas River including Lake Creek, Chalk Creek, and Evans Gulch, which are also listed on the 1998 303(d) list for elevated metal concentrations.

Segment 2b of the upper Arkansas extends from a point above the confluence with California Gulch to a point immediately above the confluence with Lake Fork. This two mile segment lies within the San Isabel National Forest and is severely impacted by heavy metal pollution from California Gulch. Segment 2c continues along the Arkansas to a point immediately above the confluence with Lake Creek. This eleven mile long segment flows south and parallel to Highway 24 and ends at Independence Pass. This segment is also impacted by the metal contamination of California Gulch and both will be affected by Superfund remediation of the California Gulch site.

Segment 3 of the upper Arkansas is a 150 mile long segment that extends from a point immediately above the Lake Creek confluence to the inlet to Pueblo Reservoir. The entire segment from Lake Creek to the inlet to Pueblo Reservoir is included on the 2008 303(d) List. The mainstem Arkansas flows southeast through the more populated towns of Buena Vista, Canon City, and Salida. This segment is also affected by metal contamination from the area upstream.

Segment 5, Halfmoon Creek, is approximately a ten mile long segment that originates at North Halfmoon Lakes and North Halfmoon Creek just southwest of Mount Massive, 14, 421 foot elevation. It then flows east and north through the Mount Massive Wilderness, across the Colorado Trail, until its confluence with the mainstem Arkansas River. One of its tributaries, South Halfmoon Creek flows past the Iron Mike Mine before it reaches its confluence with Halfmoon Creek.

Segment 7 of the upper Arkansas is a five mile long segment extending from the source of Evans Gulch to its confluence with the Arkansas River. Evans Gulch flows west, through Mountain Lake and Diamond Lake, past the Fortune Mine, Matchless Mine, above Leadville, and through the historic "mineral belt". The California Gulch Superfund site was divided into 12 Operable Units (OU), and the upper and lower portions of Evans Gulch are included in Operable Unit No. 6 (OU6).

Upper Arkansas Segment 11 includes the East and West Fork Sayres Gulch, in addition to the mainstem, which are tributaries to South Fork Lake Creek, from its source to its confluence. Sayers Gulch is 17 miles long, and flows north through the Collegiate Peaks Wilderness Area. Historically, there has been minimal anthropogenic disturbance, yet the widespread hydrothermal alteration (pyrite, various clay minerals, iron oxides, and other minerals associated with acid-sulfate alteration) continue to affect metal concentrations, namely aluminum and copper, from these sources.

Segment 12a, an almost twenty-one mile long segment of the upper Arkansas, includes the mainstem of Chalk Creek from its source to its confluence with the Arkansas River. Chalk Creek originates near Van Wirt Mountain (13,025 ft. elevation) and Chalk Creek Pass in the Sawatch Mountain range. It then flows north and east through the San Isabel National Forest through a natural hot springs until its confluence with the Arkansas River.

All of the above Arkansas River basin segments were identified on either Colorado's 1998 or 2008 303(d) List as not supporting the use classification for aquatic life due to high levels of cadmium, aluminum, lead, zinc, and/or low pH. Type (i) temporary modifications are in place for the months of April and May for segments 2b and 2c. Type (i) temporary modifications are granted "*where the standard is not being met because of human-induced conditions deemed correctable within a twenty year period*" (*31.7(3)(a).* Type (iii) temporary modifications are in place on Segments 3 and 12a, and they are applicable year round. Type (iii) temporary modifications are granted "*where there is significant uncertainty regarding the appropriate long-term underlying standard" (31.7(3)(a).* All temporary modifications are for chronic values and are set to expire on December 31, 2012. Segment 11 currently has an ambient-based acute standard for aluminum of 750 μg/L. Segments 2b and 2c also adopted recalculated site-specific acute and chronic standards for cadmium and zinc at the 2007 Arkansas Basin hearings.

The conditions under which Temporary Modifications are deemed appropriate were changed in the Basic Standards hearing in 2005. The Statement of Basis and Purpose from the 2005 hearing states (31.44 D):

> *"In cases where there are point source discharges on such segments, decisions on temporary modifications will be made on a case-by-case basis and may include consideration of the parameter of concern, whether that parameter is present in the discharge, what are the other sources of the parameter, and what are the plans to either return the water to full attainment or determine what are the appropriate underlying standards."*

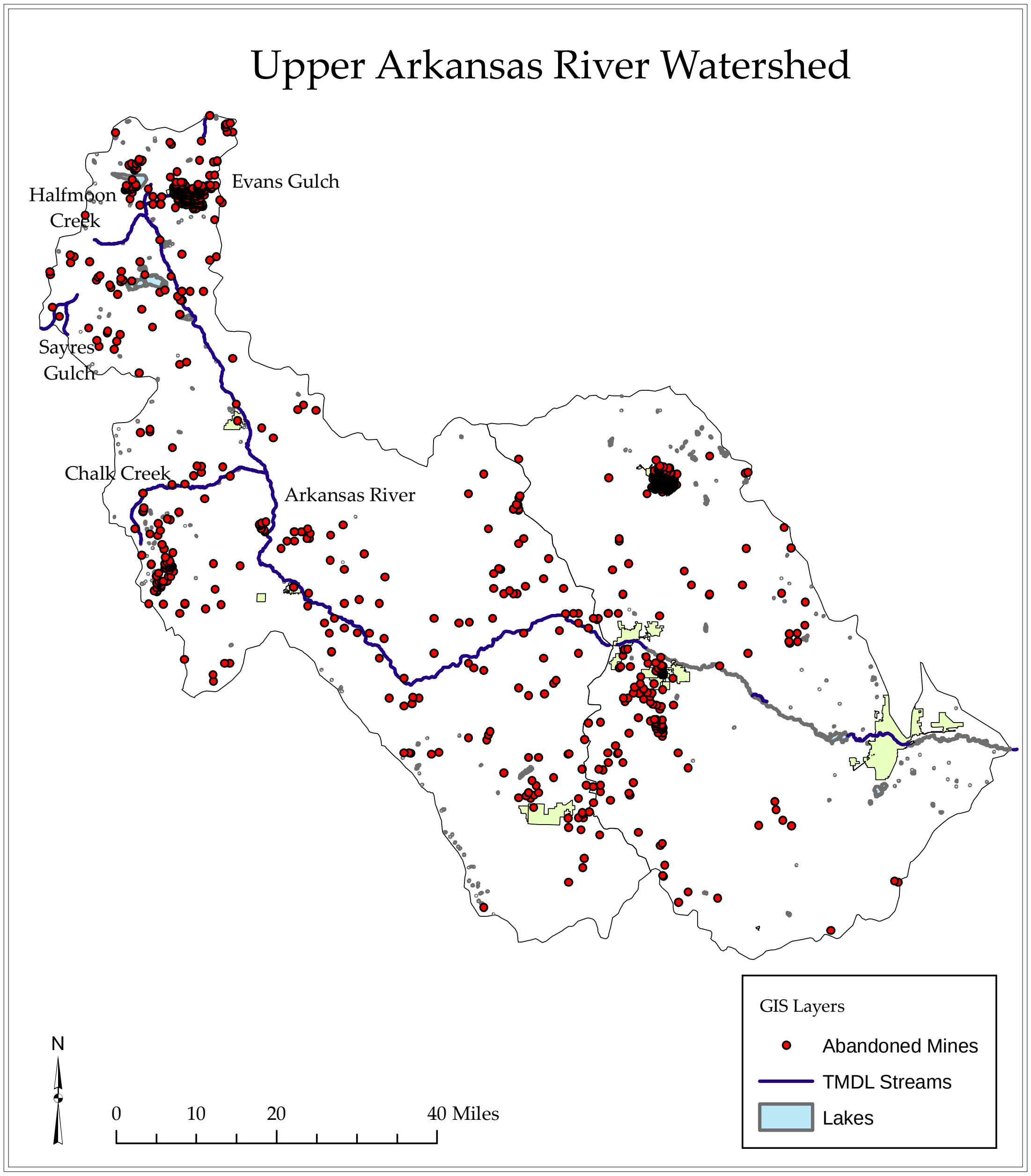


Figure 1. The upper Arkansas basin watershed.

2.2. Discharge Permits and Property Ownership

The National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. Currently, there are several active National Pollutant Discharge Elimination System (NPDES) permitted discharges into several of the listed segments in the upper Arkansas watershed. Segment 2b has two active NPDES permits, Segment 2c has one active permit, Segment 3 currently has five active discharge permits, Segment 7 has one active permit, Segment 11 has no active discharge permits, and Segment 12a has four active NPDES permits (Table 2). For most of the year, permitted dischargers are not significant loading sources (< 10%). However, during periods of low flow, permitted dischargers on Segment 3 can contribute as much as 15% of the lead load to the Arkansas River.

	Dischargers	NPDES ID	SIC DESC	Design Capacity, mgd
Segment 2b	Butala Construction Co., Inc.	COG500476	construction sand/gravel	1.38
	Lake Fork Mobile Home Park	COG588060	sewer system	0.05
Segment 2c	CDOW Fish Hatchery and Preserve	COG130015	fish hatchery/preserve	1.25
Segment 3	Buena Vista Sanitation District	CO0045748	sewer system	2.5
	City of Salida WWTF	CO0040339	sewer system	2.1
	Heart of the Rockies Regional Med. Ctr.	COG600780	domestic treatment plant	0.72
	Medical Center Replacement Hospital	COG072355	heavy construction	0.12
	Mt. Shavano Fish Hatchery	COG130003	fish hatchery/preserve	6.4
Segment 7	Parkville Water District	COG641042	sewer system	N/A
Segment 12a	Chalk Cliffs Fish Hatchery	COG130002	fish hatchery/preserve	10.2
	Mt. Princeton Hot Springs Resort	COG588017	sewer system	0.05
	Silver Cliff Ranch	COG588102	sewer system	0.05
	Young Life Campaign, Inc.	CO0034304	sewer system	0.05

Table 2. Permitted dischargers in 303(d) listed stream segments of the Upper Arkansas watershed.

2.3 History

Much of the heavy metal loading throughout the Upper Arkansas basin is the result of natural geologic conditions and historic mining activities. The upper reaches of the Arkansas River flow through the historic "mineral belt" above Leadville, Colorado. Geology and mineralization in the Leadville Mining District is highly complex and generally of three types: massive sulfide replacement deposits, veins, and high-temperature deposits characterized by magnetite, garnet, and molybdenite occurring as veins, disseminations, and replacement bodies. Sulfide mineralization containing various concentrations of lead, zinc, silver, copper, gold, and molybdenum is predominant throughout the District.

From the earliest gold discoveries in the 1860s, intermittent periods of active mining and lulls occurred within the district. The District produced silver, molybdenum, lead, zinc, copper, and gold ores. Prior to 1900, silver and lead were the primary commodities; while after 1900, zinc and molybdenum ores produced the highest values. The fine waste material remaining after the processing of metals is referred to as mine "tailings". These tailings were deposited adjacent to or directly down-gradient of the mill. In that period prior to modern environmental laws or regulations, gravity was the principal disposal method for mining wastes. Due to the sizeable quantities of mine waste rock and the slow biogeochemical process of acid rock discharge, this pollution can continue to flow long after the mining ends.

QUANTITY					
	Pounds of Bullion	Pounds of Lead	Tons of Ore	Ounces of Silver	Ounces of Gold
Total 1st Quarter	23,487,082	23,380,743	12,924	2,042,323	3,056
Total 2nd Quarter	20,510,096	20,415,647	12,175	1,838,596	2,886
Total 3rd Quarter	22,713,006	22,605,015	28,050	1,743,876	6,548
Total 4th Quarter	19,747,065	19,646,027	36,953	1,648,454	3,923
Total for 1882:	86,457,249	86,047,432	90,102	7,273,249	16,413
VALUE					
	Value of Lead	Value of Silver	Value of Gold	Value of Ore	Total Value
Total 1st Quarter	$ 1,169,037	$ 2,328,248	$ 61,120	$ 485,762	$ 1,044,167
Total 2nd Quarter	$ 1,020,779	$ 2,093,301	$ 49,720	$ 599,059	$ 3,773,772
Total 3rd Quarter	$ 1,130,251	$ 1,988,142	$ 130,960	$ 1,326,111	$ 4,575,334
Total 4th Quarter	$ 942,977	$ 1,827,561	$ 78,457	$ 1,885,134	$ 4,734,129
Total for 1882:	$ 4,263,044	$ 8,237,252	$ 320,257	$ 4,296,066	$ 14,127,402

Table 3. Bullion output of Leadville in 1882 taken from the *Engineering and Mining Journal*.

In 1983, California Gulch (COARUA06) was placed on the National Priorities List (NPL) for clean-up under Superfund because of concerns about the impact of heavy metals on the Arkansas River. Reduction of metals in upper Arkansas River segments (COARUA02b and COARUA02c) will be accomplished mainly through Superfund/CERCLA activities and treatment of abandoned mine drainage in the basin. Water quality in these listed segments will be affected by the ongoing Superfund remediation efforts.

Revisions to the water quality standard were adopted during the 2007 Arkansas/Rio Grande hearings. The current standard sets ambient water quality standards for cadmium and zinc on Segments 2b and 2c, and proposes seasonal temporary modifications for the segment during April and May.

The Colorado Geological Survey (CGS now DRMS) conducted a NASA-funded survey of the Lake Creek watershed (Segment 11) in Spring 2002 through Fall 2003. The survey used remote sensing to map the mineralogy related to water quality within the hydrothermally altered watershed and to identify the relative contributions of natural and anthropogenic sources of metals contamination (Bird and Sares et al., 2003). Historic mining in the area was limited to only a few small claims, none of which are known to discharge to the watershed. The watershed is an area of widespread hydrothermal alteration that includes pyrite, various clay minerals, iron oxides, and other minerals associated with acid-sulfate alteration. Springs discharging from this zone typically have pH below 3 and contain high concentrations of metals, including aluminum and iron exceeding 200 mg/L, copper up to 10 mg/L, and sulfate up to 29,000 mg/L (Bird and Sares et al., 2003). Hence, the area provides a unique opportunity to study the impacts from acid rock drainage (ARD) derived from primarily natural sources with only minimal anthropogenic disturbance (Bird and Sares et al., 2003).

2.4 Water Quality Target / Expected Condition

The stated target, or expected condition, of the TMDL is a reduction in metals loading within the Upper Arkansas River watershed in order to attain Aquatic Life Use-based water quality standards. Much of the loading to this segment is due to both natural and irreversible anthropogenic sources. Remediation of Segment 1b and the California Gulch (COARUA06) Superfund Site are expected to result in a loading reduction of metals to the mainstem segments below their confluence with the Arkansas River. If it is likely that the loading reductions will not attain TVS, a Use Attainability Analysis (UAA) may become necessary to determine the appropriate standards (e.g. Segments 2b and 2c). The expected condition of the listed segments following remedial activities in the watershed will be an improvement over the present condition.

III. WATER QUALITY STANDARDS

Standards Framework

Waterbodies in Colorado are divided into discrete units or "segments". The Colorado *Basic Standards and Methodologies for Surface Water*, Regulation 31(WQCC 2006b), discusses segmentation of waterbodies in terms of several broad considerations:

> *31.6(4)(b)…Segments may constitute a specified stretch of a river mainstem, a specific tributary, a specific lake or reservoir, or a generally defined grouping of waters within the basin (e.g., a specific mainstem segment and all tributaries flowing into that mainstem segment.*
>
> *(c) Segments shall generally be delineated according to the points at which the use, physical characteristics or water quality characteristics of a watercourse are determined to change significantly enough to require a change in use classifications and/or water quality standards*

As noted in paragraph 31.6(4)(c), the use or uses of surface waters are an important consideration with respect to segmentation. In Colorado there are four categories of beneficial use which are recognized. These include Aquatic Life Use, Recreational Use, Agricultural Use and Water Supply Use. A segment may be designated for any or all of these "Use Classifications":

> *31.6 Waters shall be classified for the present beneficial uses of the water or the beneficial uses that may be reasonably expected in the future for which the water is suitable in its present condition or the beneficial uses for which it is to become suitable as a goal.*

Each assigned use is associated with a series of pollutant specific numeric standards. These pollutants may vary and are relevant to a given Classified Use. Numeric pollutant criteria are identified in sections 31.11 and 31.16 of the Basic Standards and Methodologies for Surface Water.

Uses and Standards Addressed in this TMDL

The Colorado Basic Standards and Methodologies for Surface Water, Regulation 31 identifies standards applicable to all surface waters statewide (WQCC 2006b). The pollutants of concern for this assessment are dissolved cadmium, dissolved copper, dissolved lead, dissolved aluminum, pH, and dissolved zinc. The specific numeric standards assigned to the listed stream segments are contained in the Classifications and

Numeric Standards for the Arkansas River Basin, Regulation 32 (WQCC, 2006c) (Tables 4 and 5). In this instance, dissolved cadmium, dissolved copper, dissolved lead, dissolved aluminum, pH, and dissolved zinc concentrations exceed Aquatic Life Use-based standards intended to protect against short-term, acutely toxic conditions (acute) and longer-term, sub-lethal (chronic) effects. Aquatic Life Use-based standards for other parameters are attained as are all assigned numeric standards associated with Recreational, Agricultural, and Water Supply Use Classifications.

Date (Cycle Year) of Current Approved 303(d) list: 2008		
WBID	**Segment Description**	**Designated Uses & Impairment Status**
COARUA02b	Mainstem of the Arkansas River from a point immediately above California Gulch to a point immediately above the confluence with Lake Fork	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Agriculture: Not Impaired
COARUA02c	Mainstem of the Arkansas River from a point immediately above the confluence with Lake Fork to a point immediately above the confluence with Lake Creek	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Agriculture: Not Impaired
COARUA03	Mainstem of the Arkansas River from a point immediately above the confluence with Lake Creek to the inlet to Pueblo Reservoir	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Agriculture: Not Impaired Water Supply: Not Impaired
COARUA05	Halfmoon Creek	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Agriculture: Not Impaired Water Supply: Not Impaired
COARUA07	Mainstem of Evans Gulch from the source to the confluence with the Arkansas River	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Agriculture: Not Impaired Water Supply: Not Impaired
COARUA11	Mainstem of the South Fork of Lake Creek from the source to Lake Creek	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Agriculture: Not Impaired

Date (Cycle Year) of Current Approved 303(d) list: 2008		
WBID	**Segment Description**	**Designated Uses & Impairment Status**
COARUA12a	Mainstem of Chalk Creek from the source to the confluence with the Arkansas River	Aquatic Life Cold 1: Impaired Recreation E: Not Impaired Agriculture: Not Impaired Water Supply: Not Impaired

Table 4. Designated uses and impairment status for the Upper Arkansas River watershed.

Chronic and acute standards are designed to protect against different ecological effects of pollutants (long term exposure to relatively lower pollutant concentrations vs. short term exposure to relatively higher pollutant concentrations). Where chronic standards were assigned to listed segments, they were used in the Upper Arkansas River watershed TMDL because they represent a more conservative approach than the acute standards. Chronic standards represent the level of pollutants that protect 95 percent of the genera from chronic toxic effects of metals. By reducing metals concentrations to attain the chronic standards, acute standards will also be attained. Per Regulation 31, chronic toxic effects include but are not limited to demonstrable abnormalities and adverse effects on survival, growth, or reproduction (WQCC 2006b).

Water Quality Criteria for Impaired Designated Uses		
WBID	**Impaired Designated Use**	**Applicable Water Quality Criteria and Status**
COARUA02b	Aquatic Life Cold 1	Dissolved Phase Cd (1) / Not Attained Dissolved Phase Zn (1) / Not Attained
COARUA02c	Aquatic Life Cold 1	Dissolved Phase Cd (1) / Not Attained Dissolved Phase Zn (1) / Not Attained
COARUA03	Aquatic Life Cold 1	Dissolved Phase Cd (1) / Not Attained Dissolved Phase Zn (1) / Not Attained Dissolved Phase Pb (1) / Not Attained
COARUA05	Aquatic Life Cold 1	Dissolved Phase Cd (1) / Not Attained Dissolved Phase Pb (1) / Not Attained
COARUA07	Aquatic Life Cold 1	Dissolved Phase Zn (1) / Not Attained
COARUA11	Aquatic Life Cold 1	Dissolved Phase Cd (1) / Not Attained Dissolved Phase Zn (1) / Not Attained Dissolved Phase Cu (1) / Not Attained Dissolved Phase Al (1) / Not Attained Minimum pH (1) / Not Attained
COARUA12a	Aquatic Life Cold 1	Dissolved Phase Pb (1) / Not Attained Dissolved Phase Zn (1) / Not Attained
Applicable State or Federal Regulations: (1) Classifications and Numeric Standards for the Arkansas River Basin.		

Table 5. Ambient water quality criteria and status for the 303(d) listed Upper Arkansas River segments.

IV. PROBLEM IDENTIFICATION

There are two permitted dischargers to Segment 2b, one to Segment 2c, and six to Segment 3, resulting in a total of nine point source dischargers to the Arkansas mainstem. For most of the year, permitted dischargers are not significant loading sources (< 10%). However, during periods of low flow, permitted dischargers on Segment 3 can contribute as much as 15% of the lead load to the Arkansas River. There is one permitted discharger each to Segment 5 and Segment 7, and four to Segment 12a (Table 2). Permitted dischargers are not significant loading sources (< 10%) on these segments. There are currently no permitted dischargers to Segment 11.

To a great extent, heavy metal loading throughout the Arkansas River basin has been the combination of natural geologic conditions and historic mining activities as opposed to point source pollution. From the earliest gold discoveries in the 1860s, intermittent periods of active mining and lulls occurred within the district. The District produced silver, molybdenum, lead, zinc, copper, and gold ores. Prior to 1900, silver and lead were the primary commodities; while after 1900, zinc and molybdenum ores produced the highest values. The fine waste material remaining after the processing of metals is referred to as mine "tailings". These tailings were deposited adjacent to or directly down-gradient of the mill. In that period prior to modern environmental laws or regulations, gravity was the principal disposal method for mining wastes. Due to the sizeable quantities of mine waste rock and the slow biogeochemical process of acid rock discharge, this pollution continues to flow long after the mining ends.

In 1983, California Gulch (COARUA06) was placed on the National Priorities List (NPL) for clean-up under Superfund because of concerns about the impact of heavy metals on the Arkansas River, especially Segments 2b and 2c. Reduction of metals in Arkansas River basin Segments 2b and 2c will be accomplished mainly through Superfund/CERCLA activities and treatment of abandoned mine drainage in the basin. Water quality in these listed segments will be affected by the ongoing Superfund remediation efforts.

Halfmoon Creek, in Segment 5, is located in the Sawatch Mountain Range which ranges in elevation from 2969 to 4399 meters in elevation. The basin drains parts of Mount Elbert and Mount Massive, which are the second and third highest peaks, respectively, in the conterminous United States (Mast and Turk, 1999). The basin contains forested montane and subalpine zones. The northern slopes of the basin are heavily forested, whereas the south-facing slopes have sparse vegetation (Mast and Turk, 1999). Halfmoon Creek is a perennial stream that drains into Lake Fork, which is tributary to the mainstem Arkansas River. Several small natural lakes and ponds are located in the basin. The hydrology is largely controlled by melting of the annual snowpack. Variations in precipitation and temperature occur in the basin primarily because of the range in elevation. The geology of the upper basin is dominated by metamorphic rocks of Precambrian age, including biotite gneiss, schist, and migmatite (Van Loenen, 1985). Some small vein deposits have high mineral-resource potential for gold, silver, lead and zinc (Van Loenen et al. 1989). Several small, abandoned mines and an inactive mill are in the basin. Historically, small vein deposits of silver, gold, lead and zinc yielded economic quantities of these metals from Halfmoon Creek Basin. Mining activity in Halfmoon Creek Basin was, however, less than in other drainages in the Upper Arkansas River Basin (Mast and Turk, 1999).

Lake Creek is a major tributary to the upper Arkansas River located approximately 15 miles south of Leadville Colorado. Segment 11, the South Fork Lake Creek, which is listed for pH, aluminum, cadmium, copper and zinc, drains into this major tributary. The Colorado Geological Survey (CGS now DRMS) conducted a NASA-funded survey of the Lake Creek watershed (Segment 11) in Spring 2002 through Fall 2003. The survey used remote sensing to map the mineralogy related to water quality within the hydrothermally altered watershed and to identify the relative contributions of natural and anthropogenic sources of metals contamination (Bird and Sares et al., 2003). Historic mining in the area was limited to only a few small claims, which were known for relatively low producing but high-grade gold deposits, none of which are known to discharge to the watershed. Production generally came from small, Laramide gold veins in Precambrian igneous rocks (Moran and Wentz, 1974). The watershed is an area of widespread hydrothermal alteration that includes pyrite, various clay minerals, iron oxides, and other minerals associated with acid-sulfate alteration. Springs discharging from this zone typically have pH below 3 and contain high concentrations of metals, including aluminum and iron exceeding 200 mg/L, copper up to 10 mg/L, and sulfate up to 29,000 mg/L (Bird and Sares et al., 2003). Hence, the area provides a unique opportunity to study the impacts from acid rock drainage (ARD) derived from primarily natural sources with only minimal anthropogenic disturbance (Bird and Sares et al., 2003). Previous survey work has identified the South Fork as the primary source of acid and metal loadings in the Lake Creek basin. Significant dilution from the North Fork greatly reduces downstream metals concentrations.

Two relatively discreet areas have been identified as the major sources of acid and metals contamination within the South Fork drainage basin; Peekaboo Gulch and an unnamed tributary to the east fork of Sayres Gulch. The headwaters of Peekaboo Gulch include diffuse seepage from the base of Red Mountain. As the name implies, Red Mountain is rich in iron and trace metal sulfides resulting in the production of acidic, metal laden waters. Although dry mine shafts and small tailings areas are present in the area, drainage from Red Mountain appears to be the primary source of metals to Peekaboo Gulch. Sayres Gulch has been identified as the major source of acid and metals loadings within the Lake Creek drainage basin. The source is a small tributary collecting seepage from a highly mineralized ridge located approximately 4/5 mile up the East Fork Sayres Gulch.

Hard-rock mining in the Chalk Creek watershed, Segment 12a, has been extensive, continuing on and off from the late 1870's into the 1950's. Chalk Creek and its tributaries drain the eastern slopes of the Collegiate Range, and the creek enters the Arkansas River ten miles south of Buena Vista. The single greatest contributor of heavy metals in the creek is the Mary Murphy Mine, located one mile above the town of St. Elmo, followed by the Iron Chest Mine, just north of the Mary Murphy. The mine developed steeply dipping gold-silver deposits and lead-zinc sulfide fissure-vein deposits through extensive underground workings on fourteen different levels in the Tertiary-aged Mount Princeton quartz-monzonite. The two lowest adit levels, the Golf Adit and the Main Adit, continue to discharge metals at a rate of approximately 222 gallons per minute. A fish kill in 1986 was attributed to elevated levels of metals in Chalk Creek during spring runoff. Interaction between mine drainage, creek flows, and the tailings piles contribute most of the metals in the stream.

4.2 Aquatic Life Use

The high metals concentrations within the 303(d) listed segments of the Arkansas River basin exceed the standards to protect aquatic life. In spite of these high metals concentrations, aquatic life studies carried out by the Colorado Division of Wildlife (CDOW) between 1999 and 2001 demonstrated the presence of brook trout (14 to 61 lbs/acre), brown trout (0.9 to 4.7 lbs/acre), and an occasional rainbow trout in Segment 2b. Improvements in the brown trout population have been observed since the late 1990's, and trout populations continue to improve.

Similar studies were conducted on Segment 2c and Segment 3 in 1999 to 2001, and the CDOW collected brook trout, brown trout, cutthroat trout, rainbow trout, longnose suckers, and white suckers. Segment 2c and Segment 3 fish populations were dominated by brown trout with a biomass ranging from 28 to 143 lbs per acre, and

34 to 114 lbs per acre, respectively. Fish were also collected by the CDOW on Segment 5, but there was no specific data as to species type or biomass of the collected species.

No recent aquatic life data has been collected for Segment 7, Evans Gulch. However, previous sampling has shown an abundance of brook trout and a variety of aquatic macroinvertebrates typical of high mountain streams.

Segment 11 is also lacking in recent aquatic life information. Prior investigations in the early 1990's, however, failed to observe any fish in Sayres Gulch and noted limited to severely impaired macroinvertebrate populations. The limited quantity of aquatic life observed is likely the result of a combination of extremely low stream hardness and pH values resulting in an increased toxicity to metals concentrations. Once mobilized, these metals are available for uptake by organisms. A decrease in pH increases metal availability, lending itself to greater metal uptake by organisms which can cause extreme physiological damage to aquatic life.

The CDOW collected fish data in 1999, and again recently on Segment 12a. They collected brook trout, brown trout, cutthroat trout, and rainbow trout with brown trout dominating the biomass (6.8 to 80 lbs/acre). Recent aquatic life surveys observed the longnose sucker in addition to the different trout species. Currently, Colorado Division of Wildlife (CDOW) operates the Chalk Cliffs Rearing Unit in Segment 12a, which is a cold water facility that annually raises 700,000 10-inch rainbow trout. The Water Quality Control Division (WQCD) performed an antidegradation review for the fish hatchery general permit, and determined for the discharges qualifying for a general permit, that the activity will not result in significant degradation of reviewable waters with respect to adopted narrative or numeric standards as long as all of the general permit limitations are met. Monitoring requirements in the general permit are listed in Table 6. Because it has been determined that this facility does not require effluent limitations for metals constituents, it will not be given a waste load allocation in the TMDL document.

Effluent Parameter	Discharge Limitations		
	30-Day Avg	7-Day Avg	Daily Max
Flow, MGD	Report	NA	Report
Total Suspended Solids (TSS), mg/l	30.0	45.0	N/A
Oil and Grease, mg/l	N/A	N/A	10
pH, s.u. (minimum and maximum)	N/A	N/A	6.5-9.0

Table 6. Effluent limitations for Chalk Cliffs Rearing Unit on Segment 12a, Chalk Creek.

	Arkansas River			Arkansas River			Arkansas River			Halfmoon Creek			Evans Gulch			Sayre's Gulch					Chalk Creek		
	Segment 2b**			Segment 2c**			Segment 3			Segment 5			Segment 7			Segment 11					Segment 12a		
Month	Hard. ug/L	Cd-D, ug/L	Zn-D, ug/L	Hard. ug/L	Cd-D, ug/L	Zn-D, ug/L	Hard. ug/L	Cd-D, ug/L	Zn-D, ug/L	Hard. ug/L	Cd-D, ug/L	Pb-D, ug/L	Hard. ug/L	Zn-D, ug/L	Hard. ug/L	pH	Al-D, ug/L	Cd-D, ug/L	Cu-D, ug/L	Zn-D, ug/L	Hard. ug/L	Pb-D, ug/L	Zn-D, ug/L
Jan	133	1.9	497	89	1.4	352	91	0.40	115	--	--	--	100	124	--	--	--	--	--	--	56	1.3	76
Feb	132	1.9	493	90	1.4	356	87	0.38	110	--	--	--	115*	140	--	--	--	--	--	--	50	1.3	72
Mar	138	1.9	513	85	1.3	339	90	0.39	114	--	--	--	130	156	--	--	--	--	--	--	60	1.4	80
Apr	112	1.7	429	71	1.2	291	84	0.37	107	--	--	--	120	145	--	--	--	--	--	--	67	1.6	88
May	72	1.2	294	48	0.9	208	55	0.27	75	--	--	--	59	79	--	--	--	--	--	--	26	0.7	46
Jun	52	0.9	223	52	0.9	223	48	0.24	66	--	--	--	76	98	--	--	--	--	--	--	30	0.9	57
Jul	123	1.8	465	72	1.2	294	54	0.27	74	--	--	--	82	105	--	--	--	--	--	--	47	1.1	65
Aug	122	1.8	461	79	1.3	318	77	0.35	99	--	--	--	87	110	--	--	--	--	--	--	53	1.3	72
Sep	142	2.0	525	87	1.4	346	98	0.42	122	--	--	--	90	114	--	--	--	--	--	--	57	1.7	91
Oct	126	1.8	474	81	1.3	325	97	0.41	121	--	--	--	94*	118	--	--	--	--	--	--	64	1.7	92
Nov	122	1.8	461	82	1.3	329	89	0.39	113	--	--	--	98	122	--	--	--	--	--	--	71	1.7	93
Dec	162	2.2	588	99	1.5	386	101	0.43	125	--	--	--	100	124	--	--	--	--	--	--	58	1.4	78
Annual:	86	1.3	318	69	1.2	284	73	0.33	95	35	0.19	0.79	93	117	50	6.5-9.0	750	0.25	7.0	60.2	45	1.3	74

*No data were available for this month. Value is an average of the previous and following monthly averages.

Table 7. Average hardness and acute (where applicable) and chronic stream standards for 303(d) listed segments of the Arkansas River, Halfmoon Creek, Evans Gulch, Sayres Gulch, and Chalk Creek. Data are from the Resurrection Mining Company, Colorado Department of Public Health and Environment (CDPHE), Colorado Division of Wildlife (CDOW), and U.S. Geological Survey (USGS). **Site-specific cadmium and zinc standards adopted by WQCC at 2007 Arkansas Basin Hearing as follows: Cd (ac) =(1.136672-(ln(hard)*0.041838))* (e((0.9151*(ln(hard)))-3.6236)). Cd (ch) = (1.101672-(ln(hard)*0.041838))*(e((0.7998*(ln(hard)))-3.1725)). Zn (ac) = 0.978*(e((0.8537 *(ln(hard)))+2.2178)). Zn (ch) = 0.986*(e((0.8537* (ln(hard))) + 2.0469)). All other standards are Table Value standards.

V. WATER QUALITY GOALS

The water quality goal for the 303(d) listed segments of the Arkansas River basin is attainment of the Aquatic Life Cold 1 use classification. To mitigate the problematic metals loading into the upper Arkansas River watershed there are ongoing CERCLA cleanup activities associated with the California Gulch (COARUA06) Superfund site (COD980717938). California Gulch is a major tributary to COARUA02b. Twelve Operable Units (OU) of the California Gulch Superfund Site have operated at various times within the watershed. Operable Unit 1 remediation started in the 1990's with the construction and operation of a water treatment system to reduce the contamination from the Yak Tunnel. Operable Unit 2 was deleted, while OU 3 sought to remove slag piles from the Union Pacific Railroad. Operable Unit 4, Upper California Gulch, constructed water diversion channels and settling ponds to prevent the flow of heavy metals into surface water. Operable Unit 5, the Asarco Smelter, has capped and consolidated smelter waste piles. EPA is currently in the design process for remediation of OU 6, Strayhorse Gulch and Evans Gulch, while OU's 7 and 8 have completed their remediation. Operable Unit 9 addresses lead contamination in the Leadville and Lake County area. Operable Unit 10, Oregon Gulch, has been deleted while OU 11 is currently in the design phase to draw up a re-vegetation plan for the Arkansas River floodplain. Operable Unit 12 is an ongoing effort between the state of Colorado, EPA, ASARCO, Resurrection Mining, and Newmont Mining Corporation to evaluate water quality and aquatic life in the Arkansas River basin. Fish and aquatic insect populations have substantially increased since remedial actions have been completed, although further evaluations are needed to determine when acceptable cleanup levels have been achieved (http://www.epa.gov/region8/superfund/co/calgulch).

Collapses in the Leadville Mine Drainage Tunnel (LMDT) have caused water from hundreds of underground mines in the historic Leadville Mining District to back up in the mine workings and groundwater surrounding the tunnel. EPA estimates that between 500 million to one billion gallons of water is currently blocked. There is potential for a sudden release that could send a large amount of water containing elevated levels of zinc, lead and other metals through the tunnel into the Arkansas River.

In a short-term effort to alleviate concerns about a potential catastrophic failure of the Leadville Mine Drainage Tunnel, EPA is: (1) pumping water from nearby in the Gaw Shaft to pump water from the mine workings, and (2) constructing a relief well directly into the Leadville Mine Drainage Tunnel to pump water from the tunnel and transport it via pipeline to the Bureau of Reclamation's water treatment plant (http://www.epa.gov/region8/superfund/co/calgulch/mdresponse.html).

VI. INSTREAM CONDITIONS

6.1 Hydrology

The hydrograph of the Arkansas River, both upstream near Leadville and further downstream near the middle of Segment 3 (near Wellsville), is typical of high mountain streams, with low flows occurring in the late fall to early spring followed by a large increase in flow, usually in May, due to snowmelt that tails off through the summer (Figures 2 through 6). The smaller tributaries demonstrate the same pattern, but tend to show greater influences from summer rain events.

At the beginning of the Upper Arkansas River watershed, data was taken from the weather station at Twin Lakes, Colorado. Climate data for the Twin Lakes Weather Station, for the period of August 1949 through June 2007 is summarized as follows:

Average annual precipitation: 9.6 in. (244 mm.)
Month of highest precipitation: August (1.54 in. (39 mm.))
Month of lowest precipitation: January/February (0.49 in. (12.4 mm.))
Average annual snowfall: 45.2 in. (115 cm.)
Average annual temperature: 37.7º F (3.2º C)
Month of highest average temperature: July (57.6º F (14.2º C))
Month of lowest average temperature: February (19.0º F (7.2º C))
(Source: http://www.wrcc.dri.edu/summary/climsmco.html)

Median monthly flows were calculated from the nearest USGS gage where available, except for Evans Gulch and Sayres Gulch (Table 9). The gage at the Arkansas River below Leadville (USGS gage #7081200) was used to calculate loads for Segments 2b and 2c. The Arkansas River near Wellsville gage (#7093700) was used to calculate loads in Segment 3. The gage on Halfmoon Creek near Malta (#7083000) was used to calculate loads in Segment 5. Chalk Creek loads were calculated from the Chalk Creek near Nathrop gage (#7091000). The flow for Evans Gulch was calculated using GIS to estimate a ratio of watershed areas from the gage at St. Kevin's Gulch, USGS gage #7080980. The watershed area of St. Kevin's Gulch is 4.76 km^2 and the watershed area of Evans Gulch is 9.0 km^2, resulting in a ratio of 1.89.

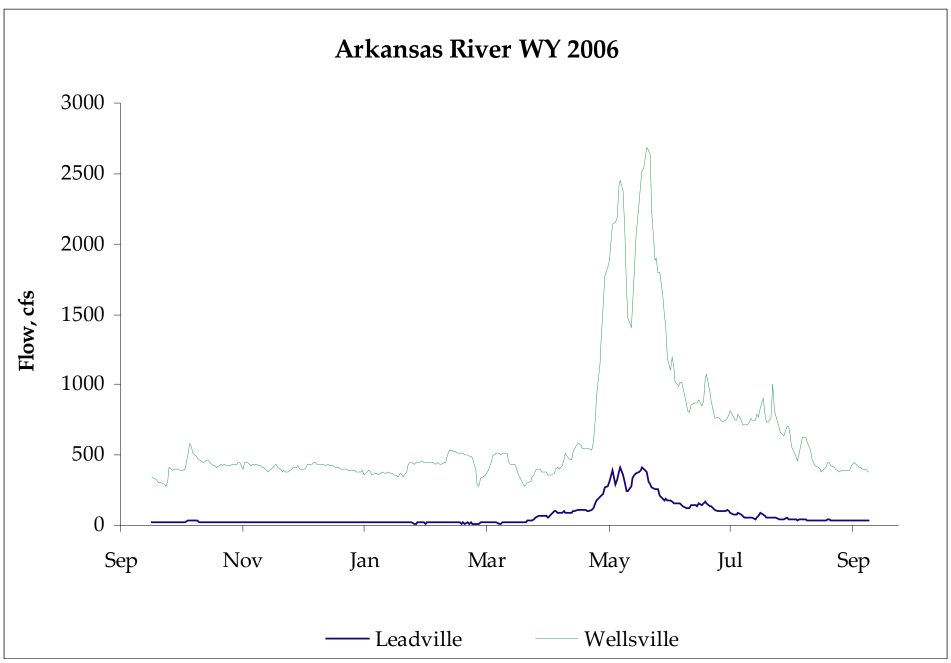
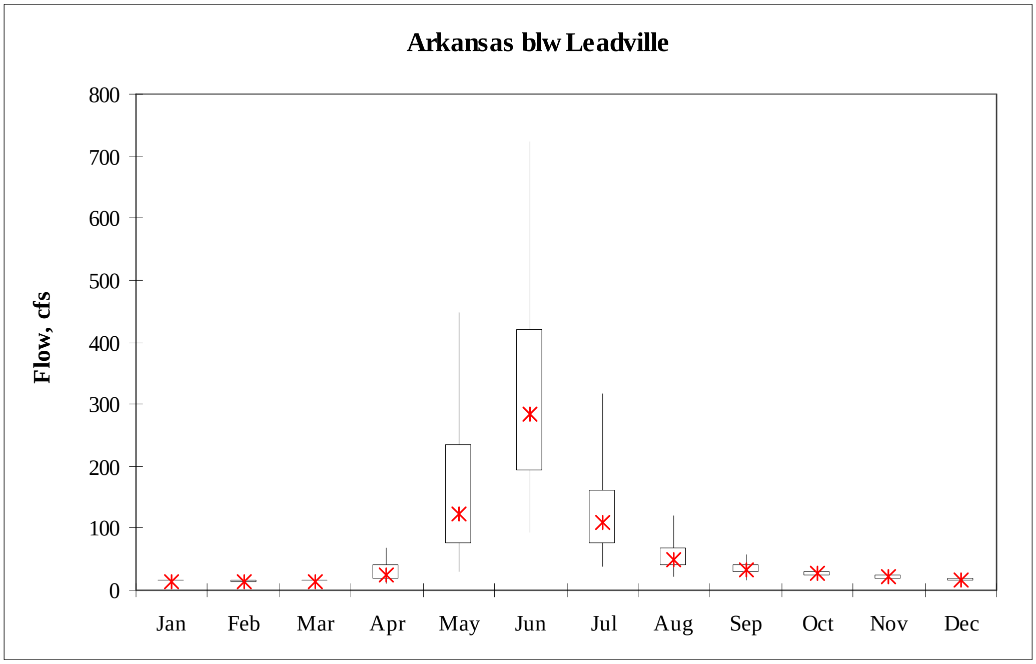


Figure 2. Hydrograph of Arkansas River below Leadville, USGS gage 7081200 and the Arkansas River near Wellsville, USGS gage 7093700.



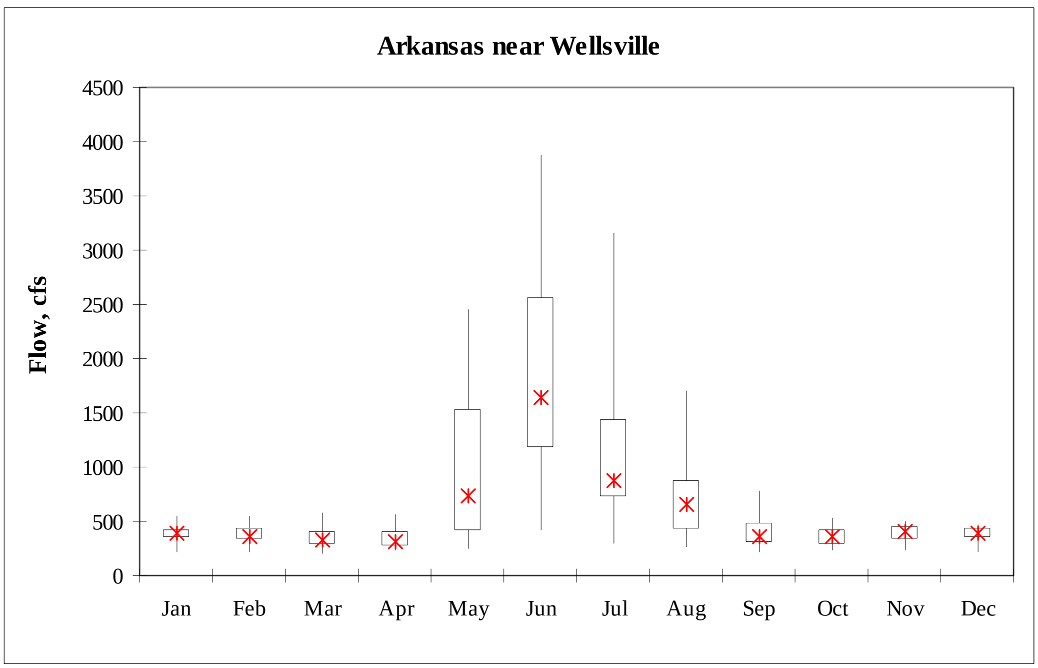


Figure 3. Box and whisker plots for flow in the Arkansas River below Leadville and near Wellsville. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median flows.

The variability in monthly stream flows along the Arkansas mainstem is illustrated in Figure 3. The largest range of flows occurs in the months of May-August. Flows at the Arkansas near Wellsville gage are almost five times that of flows recorded at the upper gage on the Arkansas below Leadville. Halfmoon Creek near Malta and Chalk Creek near Nathrop reflect similar patterns of variability although at a smaller scale (Figures 4 and 6).

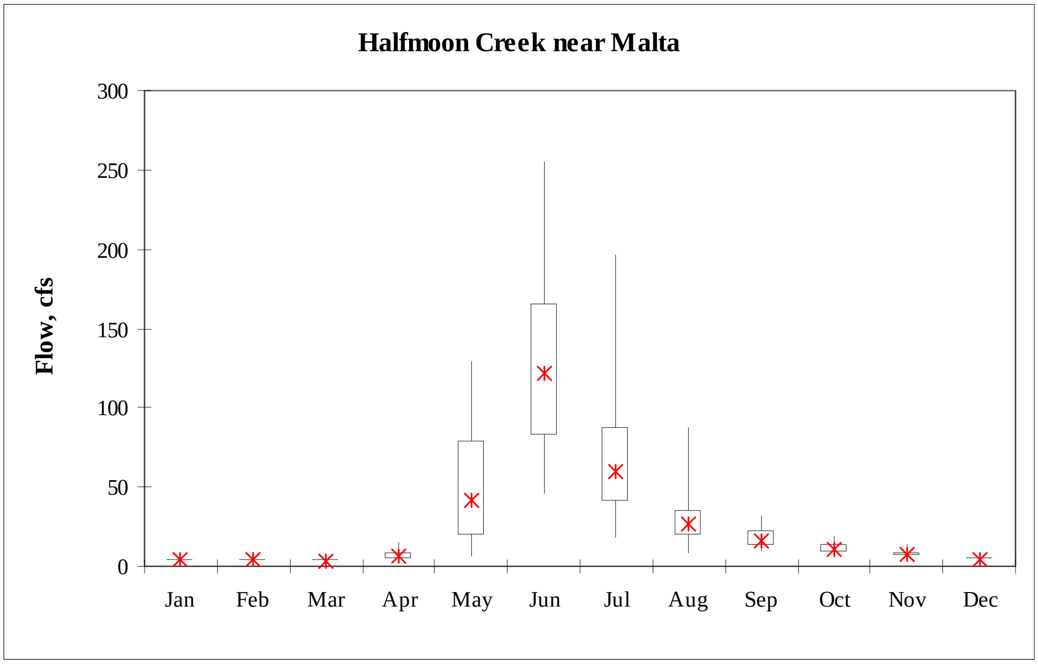


Figure 4. Box and whisker plots for flow in Halfmoon Creek near Malta. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median flows.

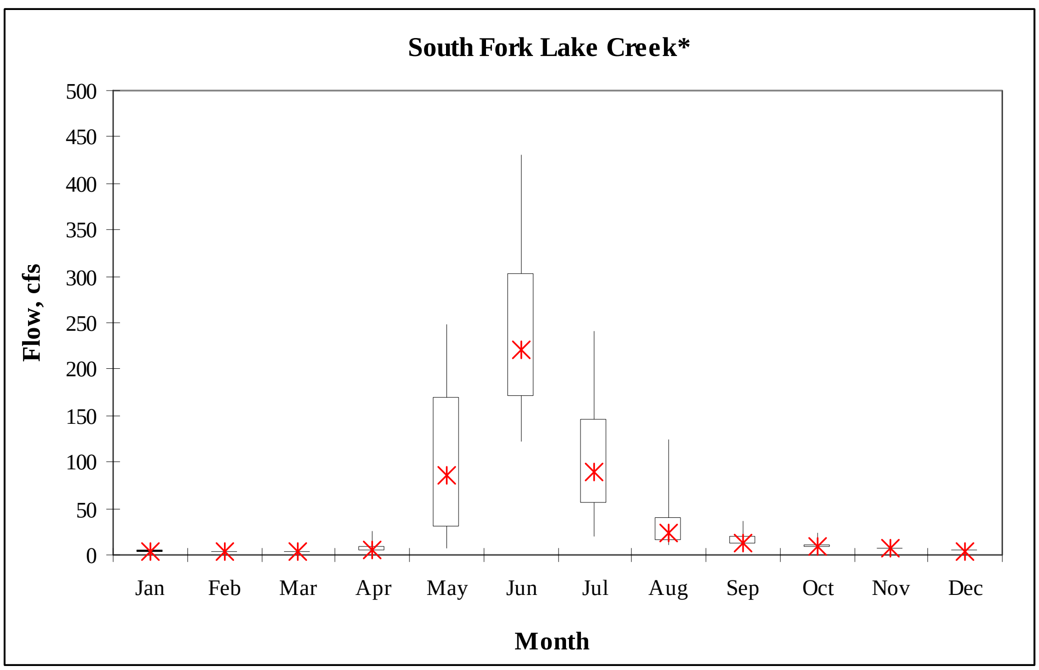


Figure 5. Box and whisker plots for estimated flow in the South Fork Lake Creek. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median flows. A ratio of watershed areas was used to estimate flows in the South Fork Lake Creek. The watershed area of the South Fork was calculated through GIS, and a ratio was developed between Lake Creek and the South Fork Lake Creek (0.30).

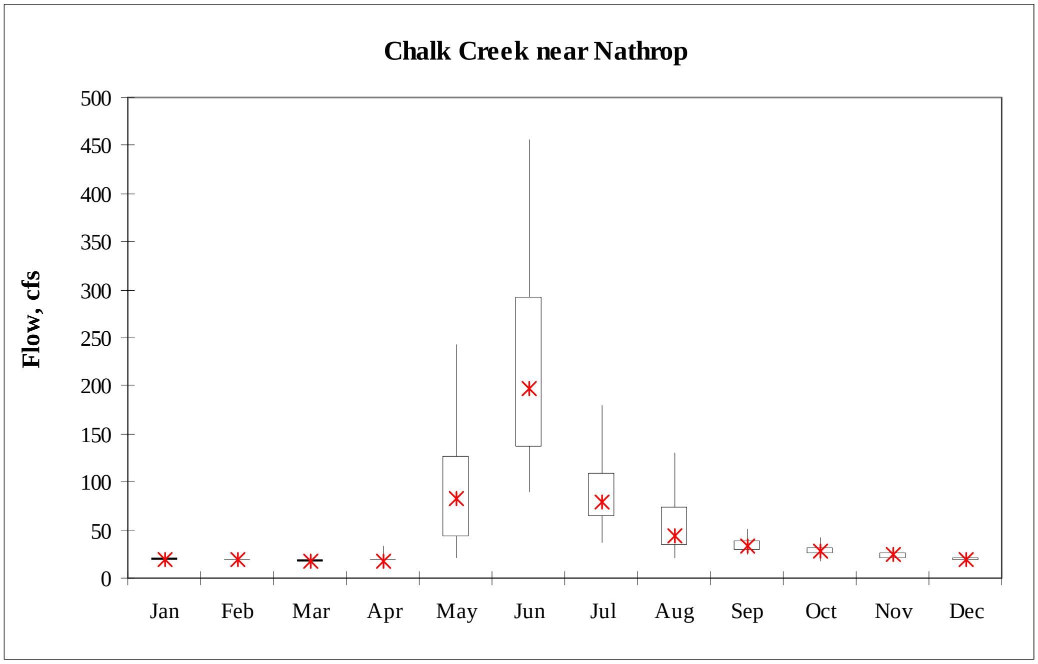


Figure 6. Box and whisker plots for flow in Chalk Creek near Nathrop. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median flows.

Ambient Water Quality Data

To identify exceedances of the chronic water-quality standard the ambient concentration of metals was calculated using the most current available data from the Resurrection Mining Company, CDPHE, CDOW, and USGS (Table 8). Per the 303(d) Assessment Methodology, ambient monthly concentrations were calculated as 85th% values. Exceedances of the standard and percent reductions needed to meet the standard for 303(d) listed segments of the Arkansas River watershed are listed in Tables 10 through 18.

Segment	Period of Record	N metals samples	Sample Location	Source
2b	2000-2005	419	Arkansas River below California Gulch	Res. Mining Co.
2c	2000-2005	320	Arkansas River below Lake Creek	Res. Mining Co./CDPHE
3	1999-2005	218	Mainstem Arkansas River	CDOW/CDPHE
5	1993-2005	4	Halfmoon Creek	CDPHE
7	1993-2006	24	Evans Gulch	CDOW/CDPHE
11	1997-2006	17	Sayres Gulch	CDPHE
12a	2000-2006	27	Chalk Creek	CDPHE

Table 8. Sources of water-quality data for 303(d) listed stream segments in the upper Arkansas River basin.

	Ark blw Leadville			Ark nr Wellsville			Chalk Cr nr Nathrop			Lake Cr above Twin Lakes			Halfmoon Cr nr Malta		
	USGS # 7081200			USGS # 7093700			USGS # 7091000			USGS #7084500			USGS #7083000		
Month	Median Flow	DFLOW, Chronic	DFLOW, Acute	Median Flow	DFLOW, Chronic	DFLOW, Acute	Median Flow	DFLOW, Chronic	DFLOW, Acute	Median Flow	DFLOW, Chronic	DFLOW, Acute	Median Flow	DFLOW, Chronic	DFLOW, Acute
Jan	15	12.2	12	386	210	199	19	19	19	10	8.4	7.7	4.2	2.5	2.2
Feb	14	12.2	11	364	209	196	19	17.4	19	9.4	8.2	7.2	4	2.5	2.1
Mar	15	12.2	13	318	209	181	18	17.4	17	9.6	8.2	7.3	3.5	2.5	2.4
Apr	25	14	14	299	209	191	18	17.4	17	16.5	8.2	7.5	6.1	2.5	2.3
May	124	20	21	706	243	229	83	18	18	285	11	17	42.0	3.1	3.9
Jun	283	23	37	1645	277	344	198	35	70	729	45	181	121.5	12	19
Jul	109	12.2	14	888	260	226	80	24	24	296	43	48	60	7.1	7.7
Aug	49	12.2	10	657	218	240	44	24	20	80	30	33	27	6.3	6
Sep	32	12.2	10	338	212	181	33	20	24	40	20	23	16	6.3	5.7
Oct	26	14	17	356	212	182	28	19	18	29	13	16	11	4.4	3.9
Nov	21	15	16	403	210	207	24	19	19	22	11	9.5	7.2	3.2	3.5
Dec	17	13	13	392	210	189	20	19	19	14	9.2	8.5	4.6	2.5	2.3

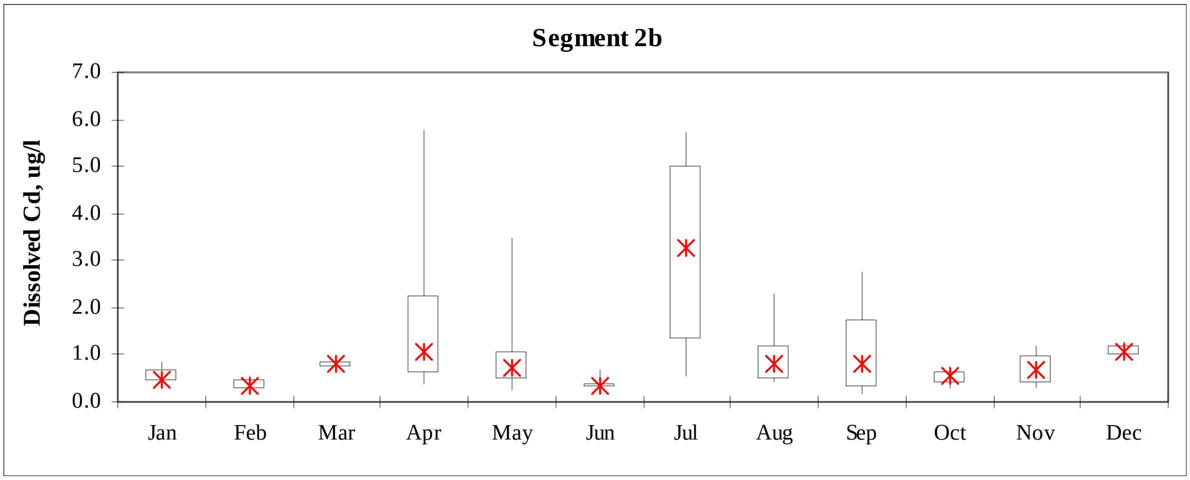
Table 9. Monthly median flows (cfs) and USEPA calculated DFLOW values for 303(d) listed stream segments in the upper Arkansas River watershed. No flow data are available for Sayres Gulch or Evans Gulch.

The combined data was used to calculate ambient water quality concentrations. Eighty-fifth percentile values were used to calculate ambient water quality concentrations in the upper Arkansas River, Halfmoon Creek, Evans Gulch, Sayres Gulch, and Chalk Creek for this TMDL.

	Avg. Hardness	Cd-D, Site-Specific Std.	Cd-D, 85th%	Cd-D % Reduction in concentration	Zn-D, Site-Specific Std.	Zn-D, 85th%	Zn-D % Reduction in concentration
Jan	133	1.9	0.8	0%	497	344	0%
Feb	132	1.9	0.5	0%	493	226	0%
Mar	138	1.9	0.8	0%	513	283	0%
Apr	112	1.7	**3.1**	61%	429	**736**	42%
May	72	1.2	**1.5**	44%	294	290	0%
Jun	52	0.9	0.5	0%	223	120	0%
Jul	123	1.8	**5.3**	76%	465	**1139**	59%
Aug	122	1.8	1.7	25%	461	**591**	22%
Sep	142	2.0	**2.2**	36%	525	**768**	32%
Oct	126	1.8	0.7	0%	474	260	0%
Nov	122	1.8	1.0	0%	461	365	0%
Dec	162	2.2	1.2	0%	588	449	0%
Annual:	86	1.3	**1.5**	35%	318	**398**	20%

Table 10. Ambient concentrations of dissolved cadmium and dissolved zinc in Segment 2b of the Upper Arkansas River basin.

Exceedances of the recently adopted site-specific, chronic cadmium standard occurred in four months of the year (April-May, July, and September) in Segment 2b. Exceedances of dissolved cadmium in Segment 2b occurred in both the rising and falling limbs of the hydrograph, but attained the standard during the peak flow month of June when dilution was available. As a result of these exceedances, eighty-fifth percentile stream concentrations annually exceed the chronic dissolved cadmium standard, calculated at an average hardness of 86 parts per million (milligrams per liter). At the bottom of Segment 2b (mainstem; California Gulch to Lake Fork), the concentration of cadmium was highest during the months prior and post-runoff, April and July, coinciding with two of the three highest monthly concentrations of zinc (Table 10, Figure 7). In addition to April and July, the ambient zinc concentration was also above the chronic site-specific standard during the months of August and September (Table 10, Figure 7). Similar to cadmium concentrations in Segment 2b, zinc concentrations exceed standards during the rising (April and May), and falling (July-September) limbs of the hydrograph. Zinc concentrations peaked in July with an eighty-fifth percentile concentration of 1139 parts per billion (micrograms per liter). Zinc concentrations in Segment 2b also did not meet the annual chronic site-specific standard. With the current chronic site-specific cadmium standard, Segment 2b would have to decrease its ambient cadmium concentration by an annual



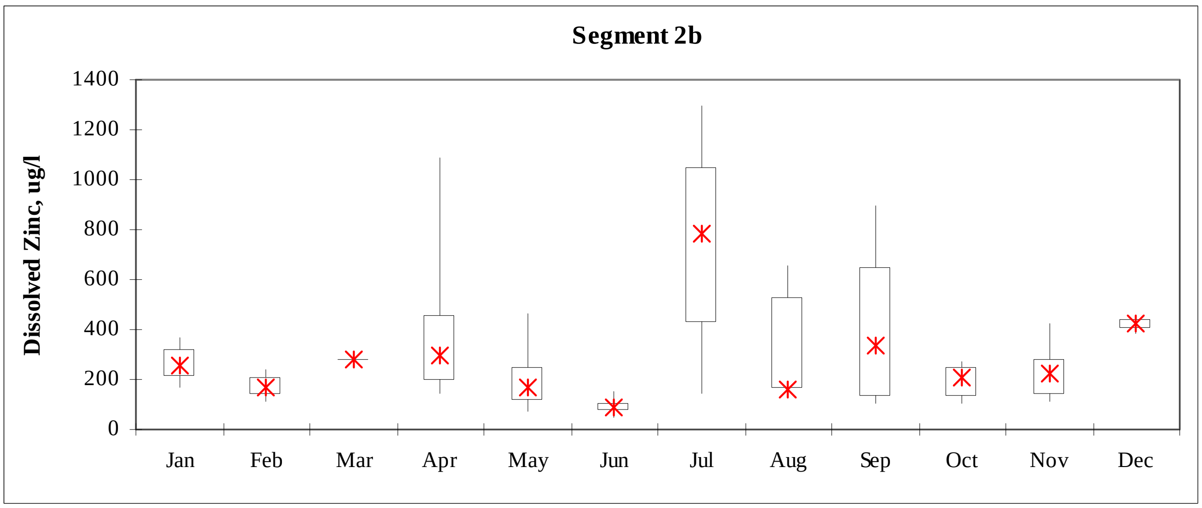


Figure 7. Box and whisker plots for dissolved cadmium and zinc concentrations in Segment 2b of the Upper Arkansas River. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median concentrations.

reduction of approximately 35% (Table 10). The majority of the reduction would occur in July with a 76% reduction and April and May with a 61% and 44% reduction required to attain the recalculated standard, respectively. In addition to cadmium, zinc concentrations would need to be reduced by approximately 20% annually to meet the current site-specific standard (Table 10). When broken down by monthly values, the reductions would need to occur in April (42%) in addition to July (59%), August (22%), and September (32%).

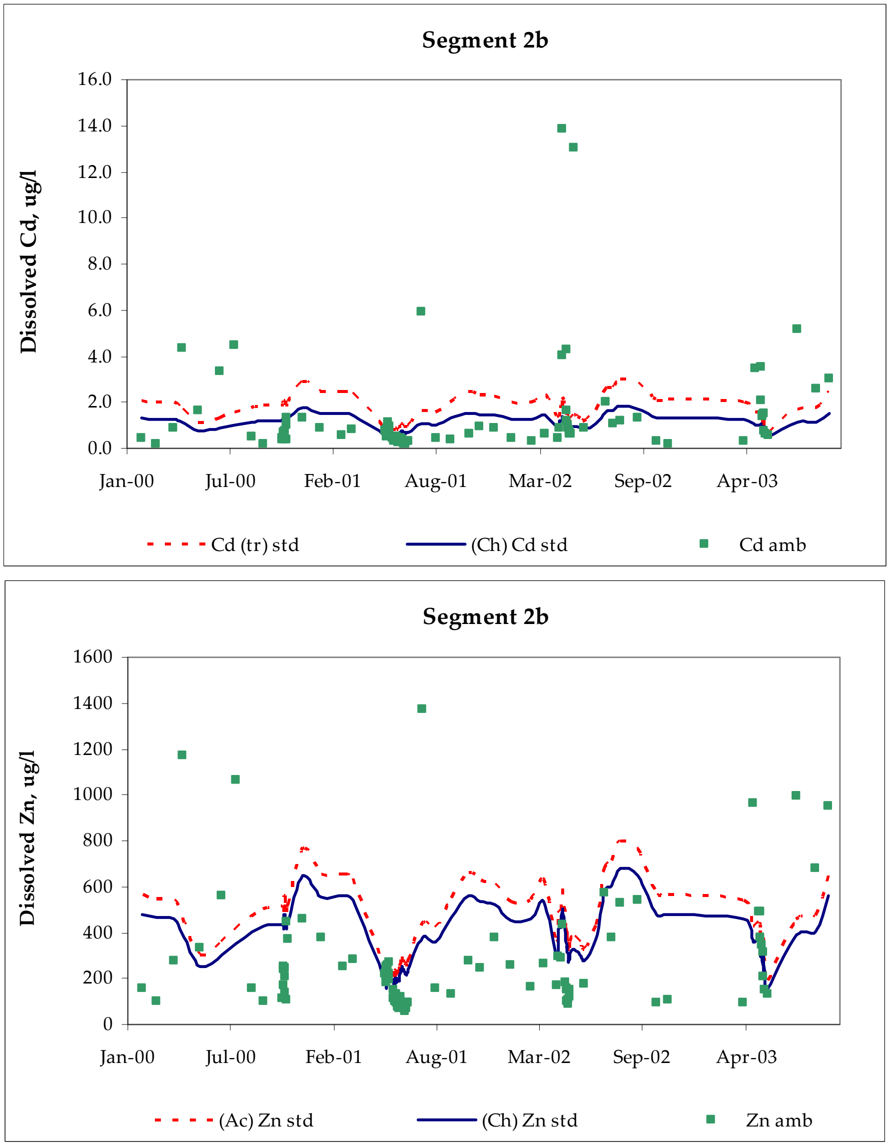


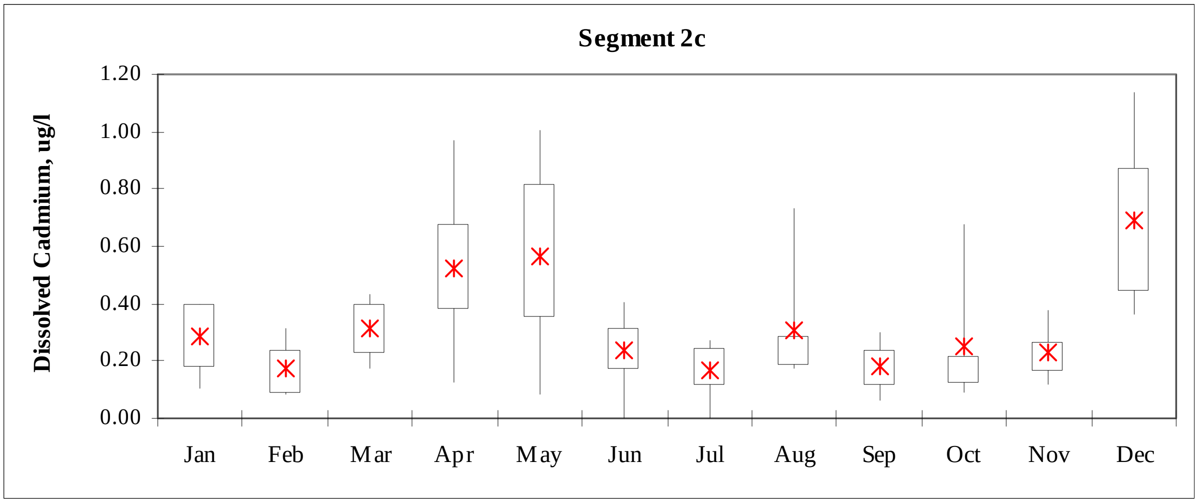
Figure 8. Acute (red dashed line) and chronic (blue solid line) standards for dissolved cadmium and zinc in Segment 2b of the Upper Arkansas River. Green squares indicate sample concentrations.

Acute exceedances of the dissolved cadmium trout standard occurred in twenty-six of the one hundred four (25%) samples taken in Segment 2b with corresponding hardness values, while acute exceedances of the dissolved zinc standard occurred in twenty of the one hundred four (19%) samples taken (Figure 8). Per Regulation 31, exceedances of the acute standard are allowed once every three years in order to attain site specific standards. Acute and chronic standards are illustrated in Figure 8 in addition to sampling data.

	Avg. Hardness	Site-Specific Cd-Std	Cd-D, 85th%	Cd-D % Reduction in concentration	Ambient Zn-Std	Zn-D, 85th%	Zn-D % Reduction in concentration
Jan	89	1.4	0.4	0%	352	147	0%
Feb	90	1.4	0.3	0%	356	108	0%
Mar	85	1.3	0.4	0%	339	115	0%
Apr	71	1.2	0.7	0%	291	206	0%
May	48	0.9	**0.9**	5%	208	**212**	2%
Jun	52	0.9	0.3	0%	223	101	0%
Jul	72	1.2	0.3	0%	294	58	0%
Aug	79	1.3	0.4	0%	318	94	0%
Sep	87	1.4	0.3	0%	346	87	0%
Oct	81	1.3	0.3	0%	325	94	0%
Nov	82	1.3	0.3	0%	329	85	0%
Dec	99	1.5	1.0	0%	386	149	0%
Annual	69	1.2	0.70	0%	284	149	0%

Table 11. Ambient concentrations of dissolved cadmium and dissolved zinc in Segment 2c of the Upper Arkansas River basin.

In Segment 2c (mainstem; Lake Fork to Lake Creek), cadmium was in attainment of the recalculated site-specific standard for all months of the year except May (Table 11). Low hardness values coinciding with an increase in flows brought Segment 2c out of attainment of the cadmium standard in May. A 5% reduction is required in the month of May to attain the chronic standard for that particular month, and no annual reductions are required to meet the annual chronic cadmium standard based on average hardness values (Table 11). Similarly, Segment 2c was in attainment of the recalculated site-specific zinc standard for all months of the year except May, where a 2% reduction is required to attain chronic standards (Table 11). The highest eighty-fifth percentile concentration of zinc (212 ppb) was observed in May and coincided with a low hardness value of 48 ppm (milligrams per liter) (Table 11). The range of cadmium values, and inherent variability, are reduced in Segment 2c as opposed to Segment 2b (Table 11 and Figure 9). Cadmium and zinc values demonstrate an annual bimodal trend, with increases in concentrations visible in April-May and a slightly smaller increase in December-January (Table 11 and Figure 9).



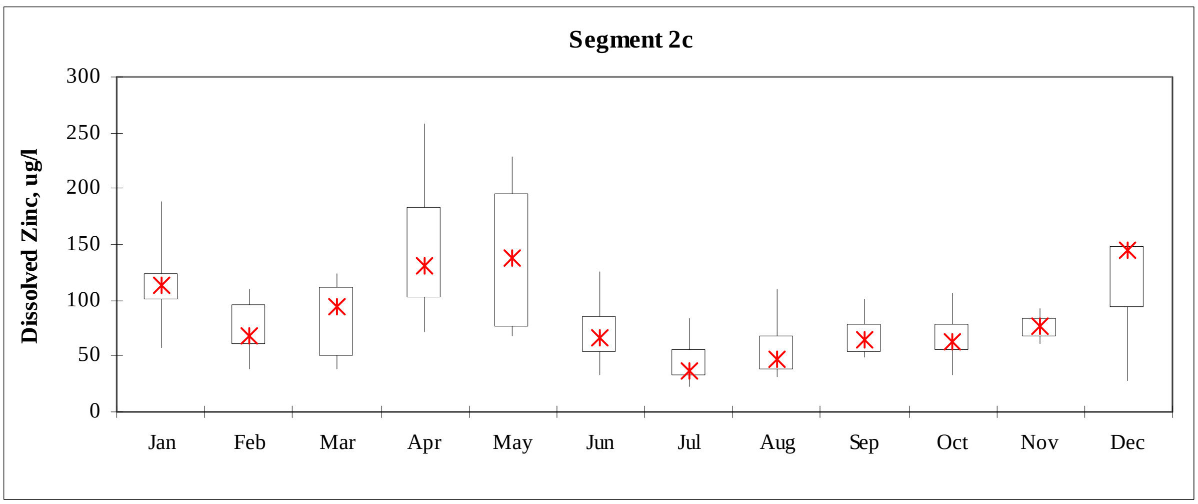
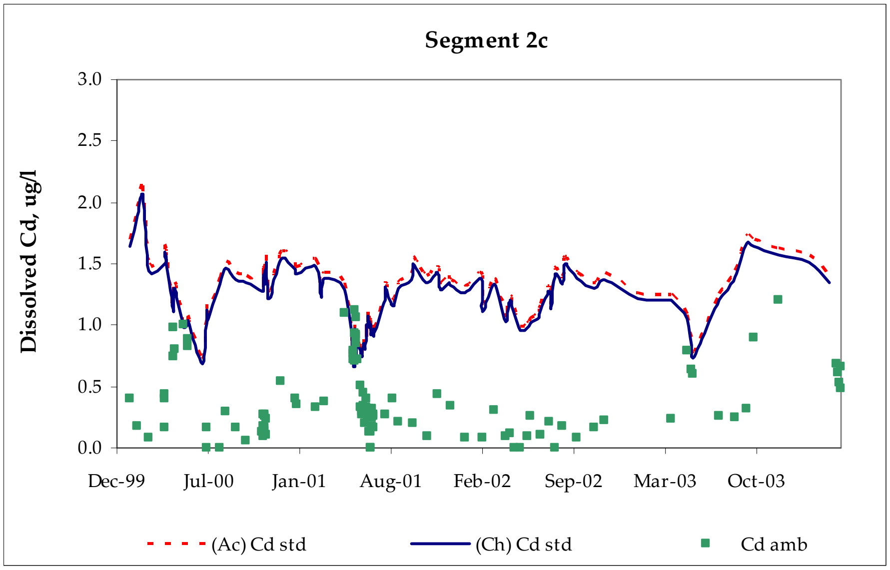


Figure 9. Box and whisker plots for dissolved cadmium and zinc concentrations in Segment 2c of the Upper Arkansas River. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median concentrations.

Acute exceedances of the dissolved cadmium standard occurred in eight of the one hundred fifty-two (5%) samples taken in Segment 2c, primarily in May of 2001. Acute exceedances of the dissolved zinc standard occurred in three of the one hundred seventy-eight (2%) samples taken, also in May of 2001. Exceedances of the acute standard are allowed once every three years in order to still attain site specific standards. Acute and chronic standards are illustrated in Figure 10 in addition to sampling data.



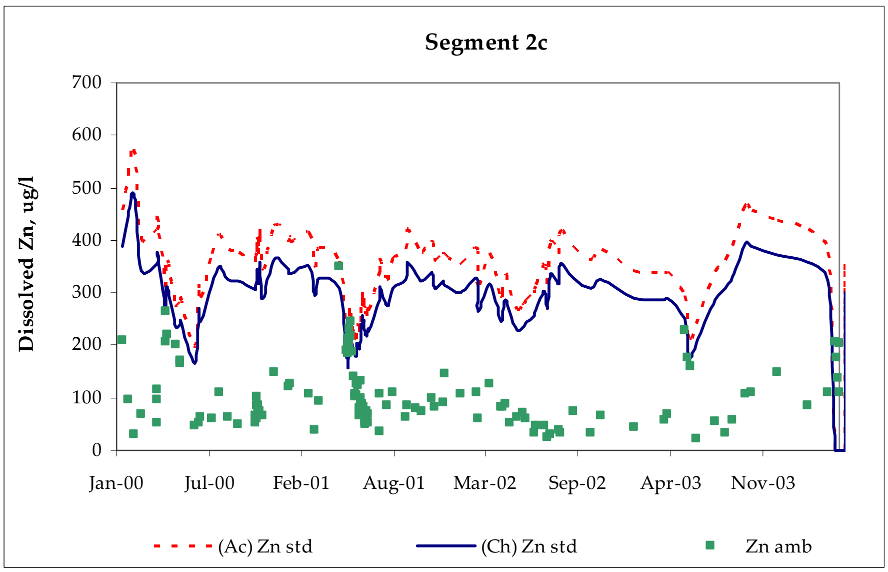


Figure 10. Acute (red dashed line) and chronic (blue solid line) standards for dissolved cadmium and zinc in Segment 2b of the Upper Arkansas River. Green squares indicate sample concentrations.

Segment 3 of the Arkansas River (mainstem; Lake Creek to Badger Creek) mainstem exceeds the dissolved cadmium standard in December and February through June. An annual reduction of 20% would be required to attain the more stringent cadmium standard recently adopted at the 2007 Arkansas/Rio Grande Basin hearings (Table 8). Lead exceeded the standard in August, which corresponded to two high lead values in 2000 and 2003 (Table 8). Zinc exceeded the standard in January through June and the month of November (Table 8). Annually, Segment 3 would require a reduction of approximately 29% to meet TVS for zinc.

Because of the length of Segment 3, ambient water quality concentrations differ considerably along the stream length. Ambient concentrations were calculated for routine sampling sites along the mainstem Arkansas River (Kobe, Otero, Granite, Buena Vista, Johnson's Village, and Salida). Dissolved cadmium concentrations were highest at the most upstream sampling point, CDOW site AR-6, Arkansas at Kobe, with an annual ambient concentration of 0.57 micrograms per liter (Figure 11). Cadmium levels decrease to below detectable limits at mainstem Arkansas sites at Johnson's Village and Salida (Figure 11). Conversely, dissolved lead concentrations were 0 micrograms per liter for sampling sites in the upstream portion of Segment 3. Ambient concentrations increased in the downstream reach, peaking at the WQCD site #7140, Arkansas at Salida, with an annual concentration of 1.7 micrograms per liter (Figure 12). Similar to cadmium, zinc concentrations were highest at the most upstream sampling point, CDOW site AR-6, Arkansas at Kobe, with an annual ambient concentration of 169 micrograms per liter (Figure 13). Zinc concentrations of 35 micrograms per liter were well below TVS standards at the most downstream sampling site, Arkansas at Salida (Figure 13).

When the data for Segment 3 were compiled, exceedances of the chronic cadmium and zinc standards occurred. The variability in monthly cadmium concentrations is illustrated in Figure 14. Cadmium exceeded the chronic standard in February through June, and December. Reductions in cadmium concentrations ranged from 9% in March to 64% in May, in order to attain chronic standards (Table 12). Overall, a 20% reduction in cadmium concentrations is needed annually to attain the chronic standard. There were no exceedances of the acute cadmium standard in the three hundred seventeen samples.

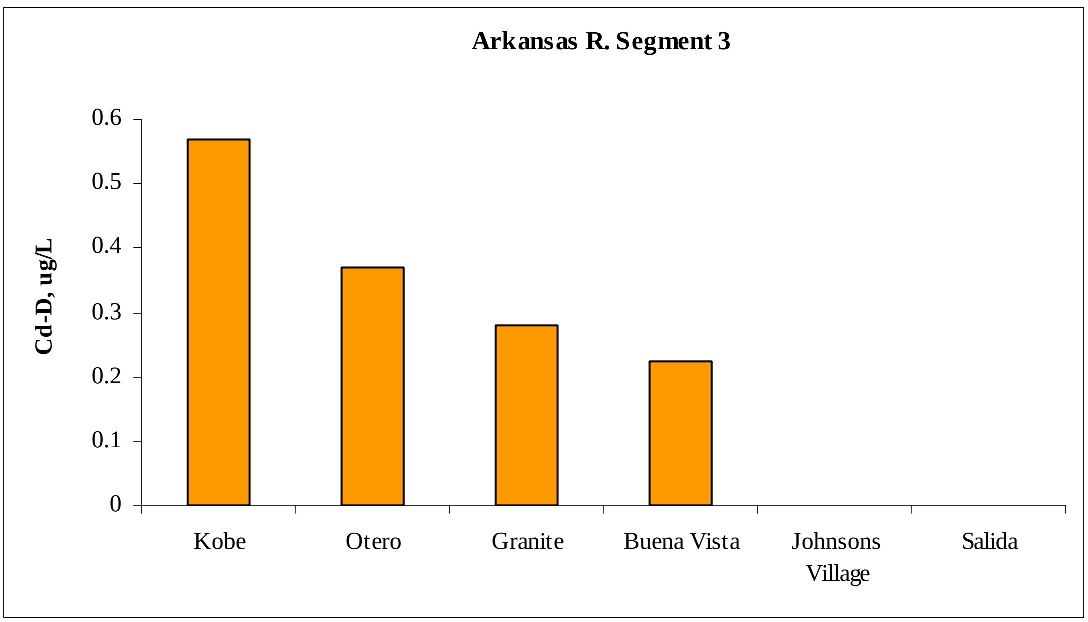


Figure 11. Ambient 85^{th} % cadmium concentrations for routine sampling sites along the mainstem Arkansas River Segment 3 (Kobe, Otero, Granite, Buena Vista, Johnson's Village, and Salida).

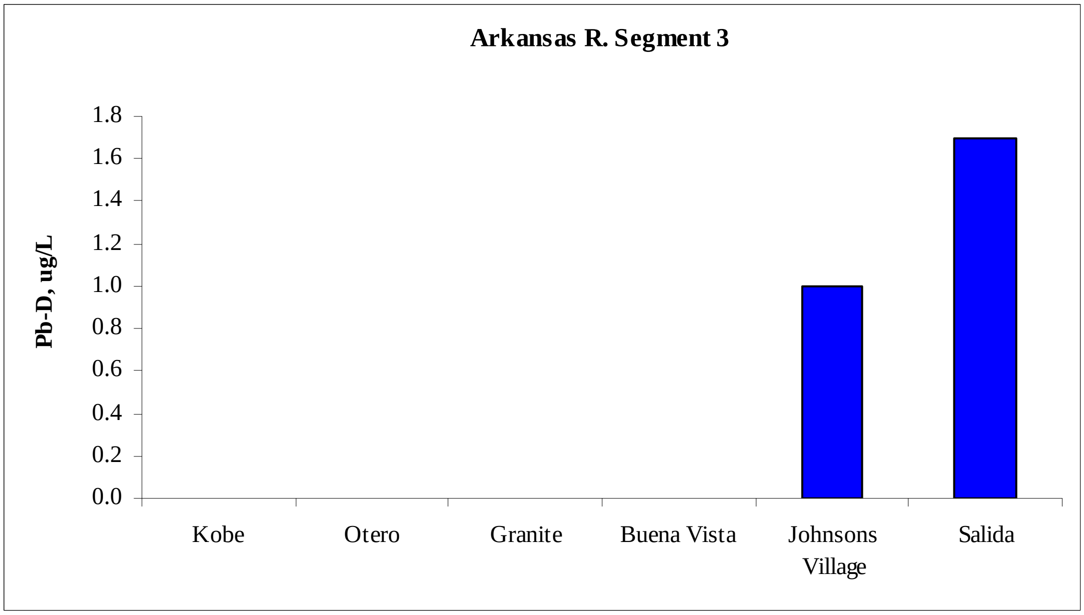


Figure 12. Ambient 85th % lead concentrations for routine sampling sites along the mainstem Arkansas River Segment 3 (Kobe, Otero, Granite, Buena Vista, Johnson's Village, and Salida).

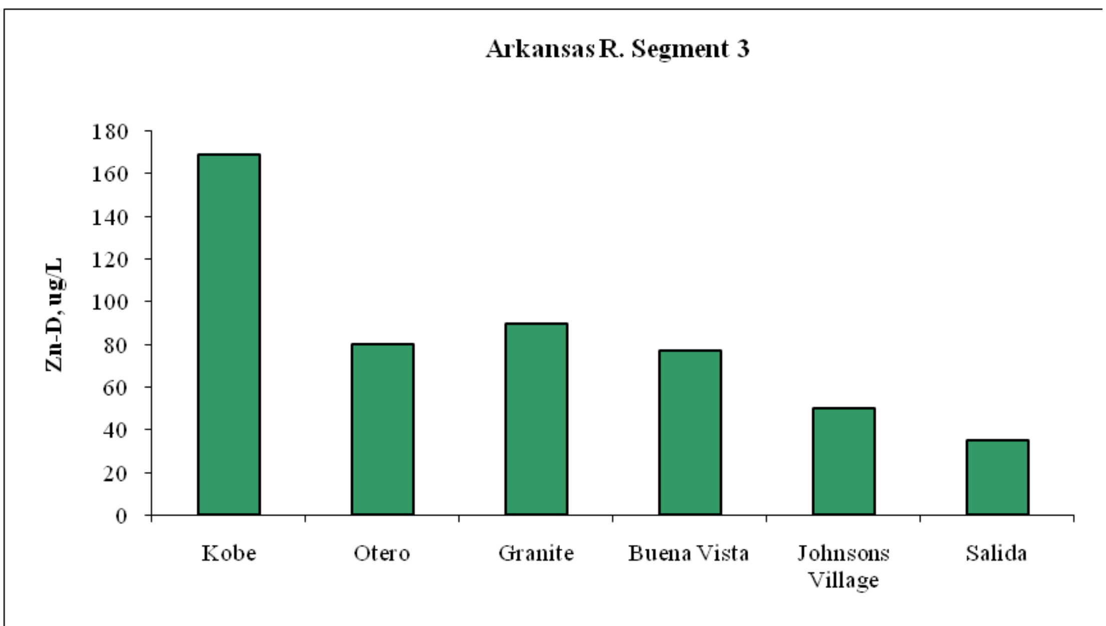


Figure 13. Ambient 85th % zinc concentrations for routine sampling sites along the mainstem Arkansas River Segment 3 (Kobe, Otero, Granite, Buena Vista, Johnson's Village, and Salida).

	Avg. Hardness	Cd-Std, TVS	Cd-D, 85th%	Cd-D % Reduction in concentration	Pb-Std, TVS	Pb-D, 85th%	Pb-D % Reduction in concentration	Zn-Std, TVS	Zn-D, 85th %	Zn-D % Reduction in concentration
Jan	91	0.40	0.32	0%	2.27	0.0	0%	115	64	0%
Feb	87	0.38	**0.52**	26%	2.16	0.0	0%	110	89	0%
Mar	90	0.39	**0.43**	9%	2.24	0.0	0%	114	109	0%
Apr	84	0.37	**0.48**	23%	2.08	1.7	0%	107	90	0%
May	55	0.27	**0.75**	64%	1.31	1.0	0%	75	**183**	59%
Jun	48	0.24	**0.30**	19%	1.12	0.0	0%	66	**78**	15%
Jul	54	0.27	0.19	0%	1.28	0.0	0%	74	53	0%
Aug	77	0.35	0.26	0%	1.89	**2.9**	34%	99	56	0%
Sep	98	0.42	0.21	0%	2.46	0.0	0%	122	87	0%
Oct	97	0.41	0.24	0%	2.43	0.8	0%	121	65	0%
Nov	89	0.39	0.26	0%	2.22	0.0	0%	113	96	0%
Dec	101	0.43	**0.51**	15%	2.54	0.0	0%	125	68	0%
Annual	73	0.33	0.41	20%	1.78	0.0	0.0	95	98	3%

Table 12 Ambient concentrations of dissolved cadmium, dissolved lead and dissolved zinc in Segment 3 of the Upper Arkansas River basin.

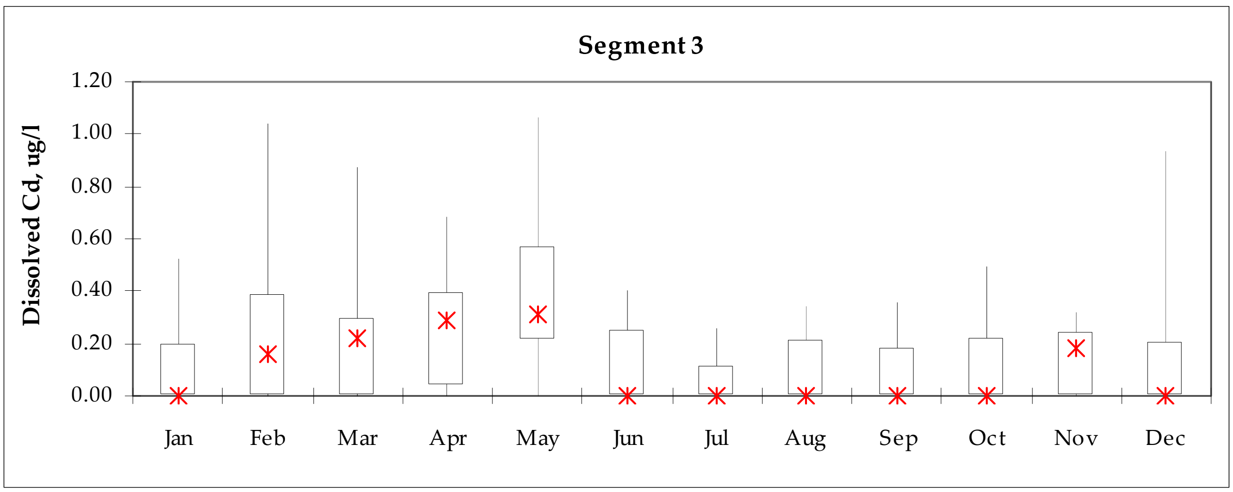


Figure 14. Box and whisker plots for dissolved cadmium concentrations in Segment 3 of the Upper Arkansas River. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median concentrations.

Segment 3 was de-listed for dissolved lead in 2008, but data are included in this TMDL (Figure 15). Table 12 demonstrates the monthly eighty-fifth percentile instream lead concentrations. April, May, August, and September are the only months that show detectable lead concentrations. Of those four months, only one month, August, exceeds the chronic standard (34% required reduction). However, when viewed on an annual basis, Segment 3 is in attainment of the chronic stream standard. There were no exceedances of the acute cadmium standard in the two hundred six samples.

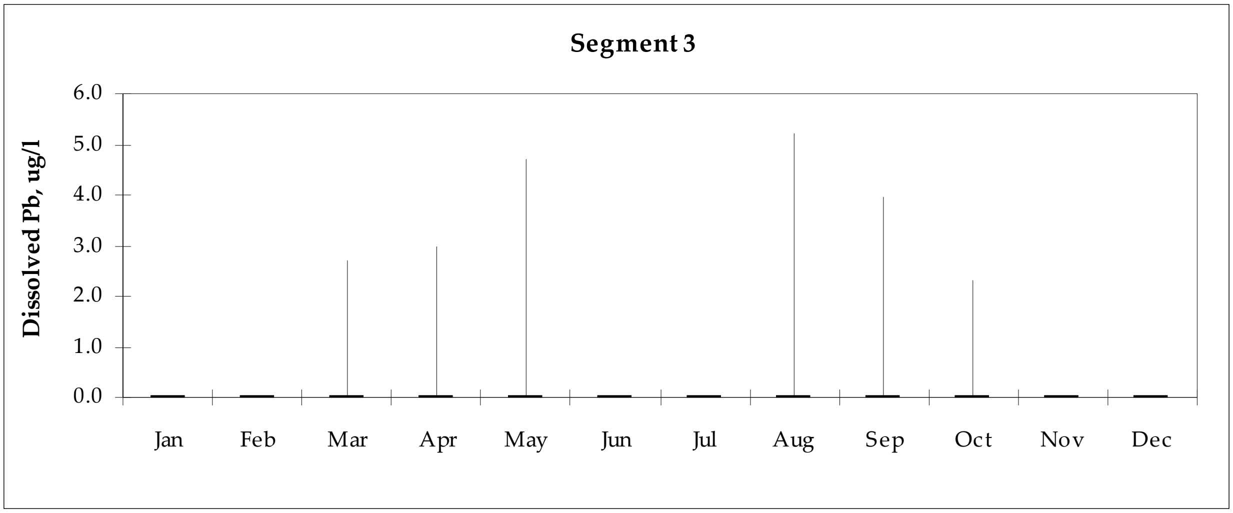


Figure 15. Box and whisker plots for dissolved lead concentrations in Segment 3 of the Upper Arkansas River. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median concentrations.

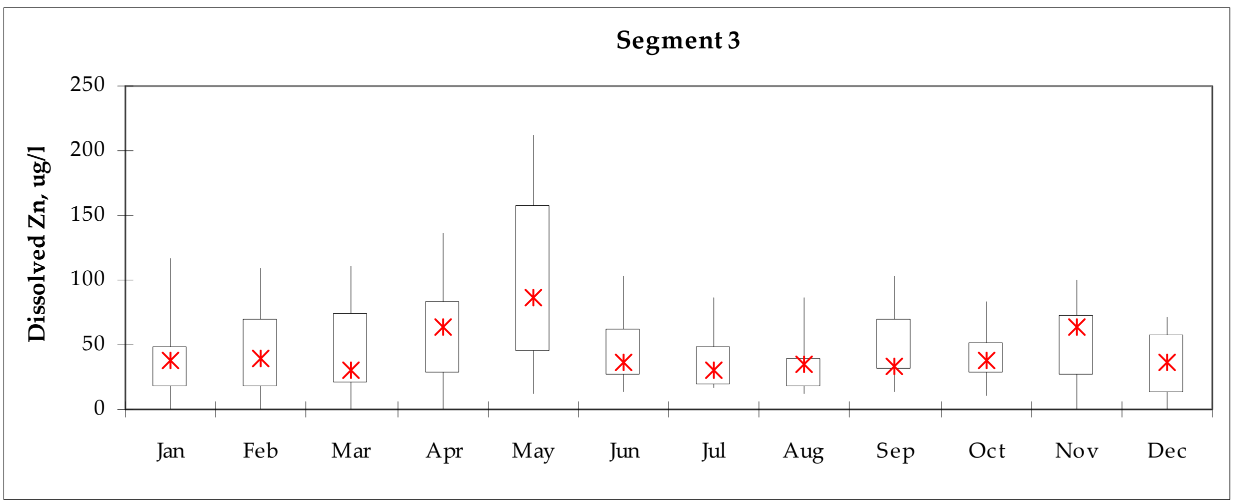


Figure 16. Box and whisker plots for dissolved zinc concentrations in Segment 3 of the Upper Arkansas River. Boxes represent upper and lower quartile values while whiskers represent 5th and 95th percentile values. Red * indicate median concentrations.

The compilation of Segment 3 data yields exceedances of both the acute and chronic zinc standards. The variability in monthly zinc concentrations is illustrated in Figure 16. Despite the variability in monthly zinc concentrations, zinc only exceeded the chronic standard for the entire segment in May and June during peak runoff. Reductions in zinc concentrations ranged from 59% in May to 9% in June, in order to attain chronic standards. Overall, a 3% annual reduction in zinc concentrations is needed to attain the chronic standard. There were fifty-four exceedances of the acute zinc standard in the three hundred seventy-four samples (14%). Twenty-six of the fifty-four (48%) acute exceedances occurred at the most upstream site, CDOW site AR-6, Arkansas at Kobe. Five exceedances occurred at the Otero Pump Station site (9%), sixteen exceedances occurred at the Arkansas River at Granite (30%), five exceedances occurred on the Arkansas at Buena Vista (9%), and two exceedances (4%) occurred at the Arkansas at Johnson Village. No acute exceedances of the zinc standard occurred at the WQCD site, Arkansas at Salida.

Not enough data was available to assess seasonality in ambient cadmium or lead concentrations in Segment 5, Halfmoon Creek (N = 5, 4), therefore an annual ambient concentration was calculated. This listed portion of Segment 5, Halfmoon Creek, exceeded the chronic cadmium and lead standards at both sampling sites, Halfmoon Creek below North Fork Halfmoon Creek and Halfmoon Creek near Leadville (Table 9). Since Halfmoon Creek exhibits low hardness values, exceedances of table value standards are common. The site at Halfmoon Creek below the North Fork Halfmoon Creek exhibited lower cadmium and lead concentrations than the site Halfmoon Creek near Leadville with concentrations of 0.7 micrograms per liter cadmium versus 3.4 micrograms per liter of cadmium and 8.0 micrograms per liter lead versus 14.4 micrograms per liter of lead (Table 13).

Four acute cadmium exceedances occurred at the site, Halfmoon Creek near Leadville (80%) (Figure 17). There were no acute exceedances of the dissolved lead standard (Figure 18).

	Hardness, mg/L	Cd-D, TVS	Cd-D, ug/L	% Reduction	Pb-D, TVS	Pb-D, ug/L	% Reduction
Halfmoon Creek below North Fork Halfmoon Creek (7183A)	33	0.18	0.7	74%	0.74	8.0	91%
Halfmoon Creek near Leadville (7183)	35	0.19	3.4	94%	0.79	14.4	95%

Table 13. Ambient concentrations of dissolved cadmium and dissolved lead Segment 5, Halfmoon Creek, in the Upper Arkansas River basin.

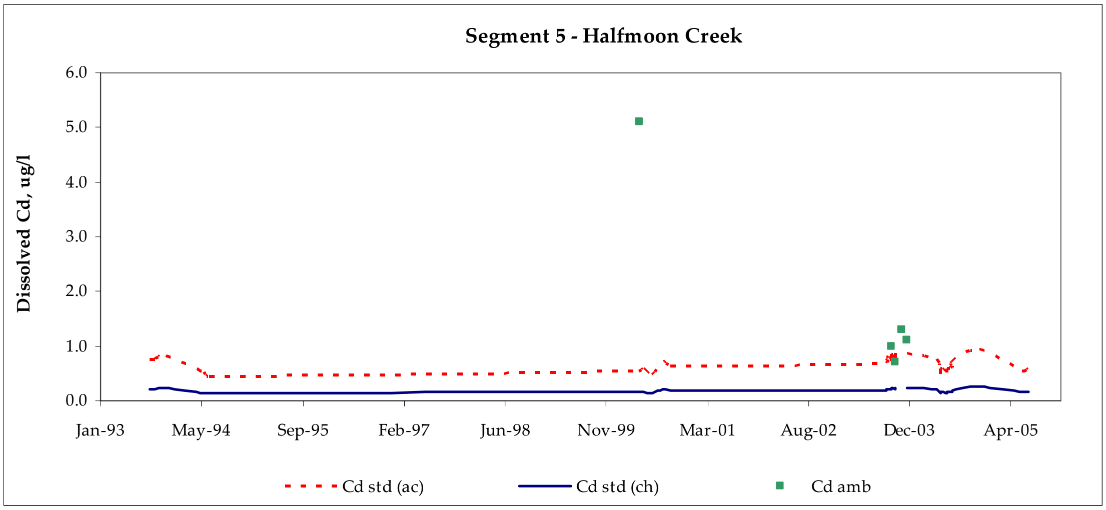


Figure 17. Acute (red dashed line) and chronic (blue solid line) standards for dissolved cadmium in Segment 5, Halfmoon Creek, in the Upper Arkansas River Basin. Green squares indicate sample concentrations.

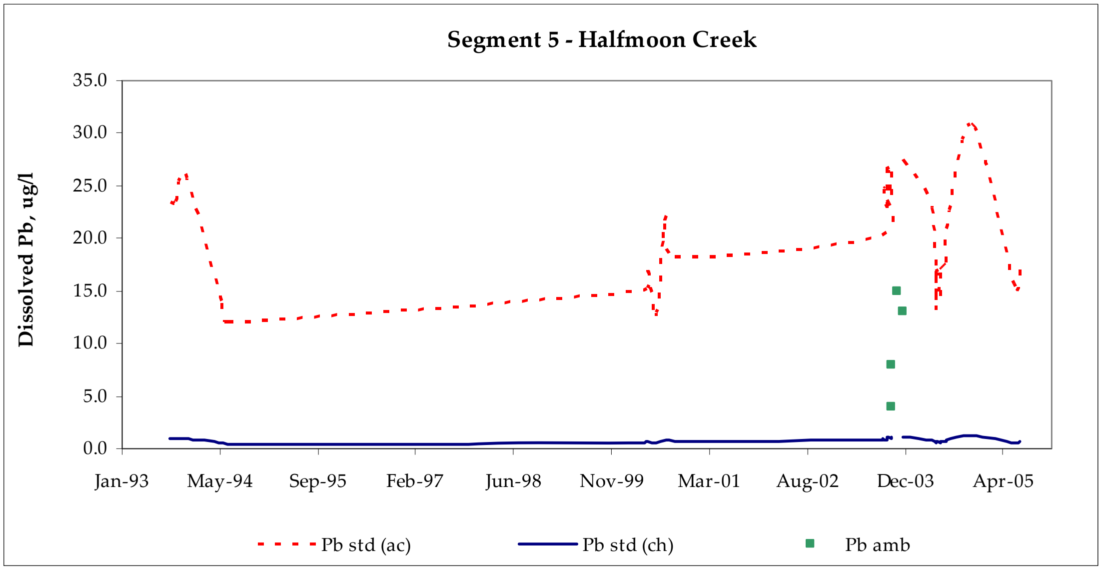


Figure 18. Acute (red dashed line) and chronic (blue solid line) standards for dissolved lead in Segment 5, Halfmoon Creek, in the Upper Arkansas River Basin. Green squares indicate sample concentrations.

In Segment 7 (Evans Gulch), zinc exceeded the standard in May, July and August (Table 10). Elevated concentrations of zinc were correlated with lower hardness values in those months (Table 10). The increase in flow at spring runoff may have produced a flushing effect for zinc in Evans Gulch, resulting in an exceedance of chronic TVS. The high zinc values were observed at CDOW site EG2, Evans Gulch at Highway 91 and 24 in the year 1995. In the more recent period of record, no exceedances of the zinc standard have occurred. Load reductions range from 3% in August to 21% in May (Table 14). Annually, no reduction of zinc concentration is required to meet the current standard (Table 14).

	Avg. Hardness	Zn-D, TVS	Zn-D, 85th%	% Reduction
Jan	100	124	27	0%
Feb	115	140	23	0%
Mar	130	156	18	0%
Apr	120	145	18	0%
May	59	79	**100**	21%
Jun	76	98	66	0%
Jul	82	105	**114**	8%
Aug	87	110	**114**	3%
Sep	90	114	15	0%
Oct	94	118	16	0%
Nov	98	122	16	0%
Dec	100	124	15	0%
Annual	93	117	113	0%

Table 14. Ambient concentrations of dissolved zinc in Segment 7, Evans Gulch, in the Upper Arkansas River basin.

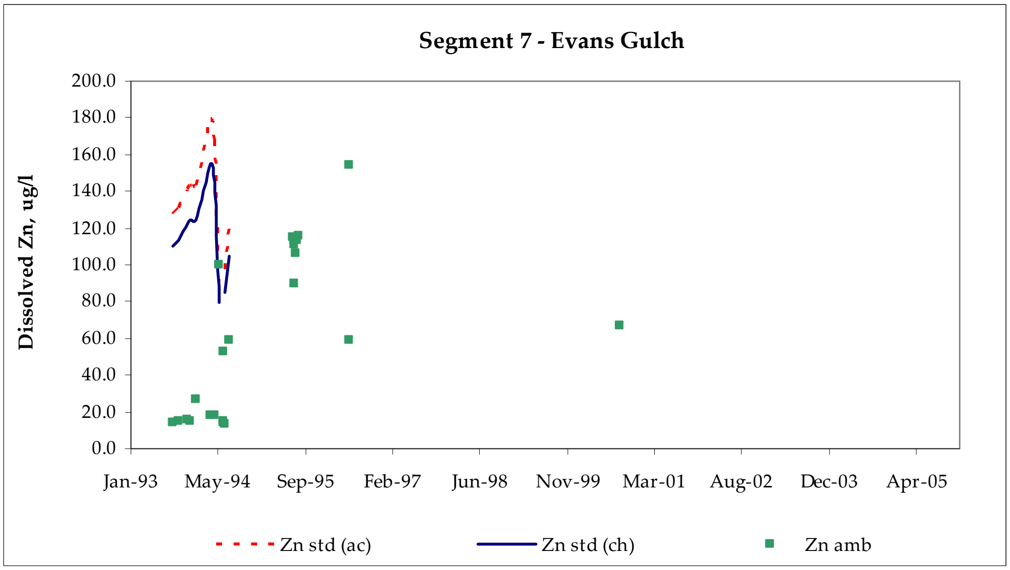


Figure 19. Acute (red dashed line) and chronic (blue solid line) standards for dissolved zinc in Segment 7, Evans Gulch, in the Upper Arkansas River Basin. Green squares indicate sample concentrations.

WQCD Site	Hardness	pH, Std	pH	Al-D, Std.	Al-D	Cd-D, TVS	Cd-D	Cu-D, TVS	Cu-D	Zn-D, TVS	Zn-D
S. Fork Lake Creek Upstream Sayres Gulch	42	6.5-9.0	6.7	750	2900	0.22	0.42	4.27	61	51.9	95
S. Fork Lake Creek Below Sayres Gulch	38	6.5-9.0	5.4	750	2940	0.20	0.00	3.92	245	47.7	50
Sayres Gulch Above Confluence with Lake Creek	69	6.5-9.0	4.5	750	43800	0.32	2.06	6.52	1918	79.2	242
E. Fork Sayres Gulch Upstream W. Fork Sayres Gulch	73	6.5-9.0	4.7	750	29000	0.33	1.20	6.84	1711	83.1	266
W. Fork Sayres Gulch Upstream E. Fork Sayres Gulch	41	6.5-9.0	6.6	750	--	0.22	--	4.18	56	50.8	23
Annual	50	6.5-9.0	4.6	750	36600	0.25	1.32	6.99	1840	60.2	141

Table 15. Ambient stream concentrations of pH, dissolved aluminum, dissolved cadmium, dissolved copper, and dissolved zinc in Segment 11, Sayres Gulch, in the Upper Arkansas River basin.

There was one acute zinc exceedance in eleven total paired samples (9%) in May of 1994 at the site, Evans Gulch at Leadville (Figure 19). The zinc concentration may be exacerbated by a drop in hardness values from 120 mg/l to 59 mg/l with the increase in dilution flow.

In Segment 11 (Sayres Gulch), pH, aluminum, cadmium, copper, and zinc annually exceeded acute and chronic water-quality standards (Table 15). Segment 11 contains only acute standards for dissolved aluminum and dissolved copper, therefore, ambient aluminum and copper concentrations were calculated as ninety-fifth percentile values. Because of lack of data at this site, concentrations were broken down into individual sampling sites. Data from Lake Creek and the South Fork Lake Creek were included in the analysis, since their water quality is significantly impacted by the water quality of Sayres Gulch. The ambient fifteenth percentile pH concentration was lowest at Sayres Gulch immediately above the confluence with Lake Creek, while the zinc concentration was the second highest. The highest concentration of zinc occurred on the East Fork of Sayres Gulch concomitant with the second lowest pH value. The highest concentrations of aluminum and copper are found at a site on the East Fork of Sayres Gulch upstream of the West Fork and immediately above the confluence with Lake Creek (Table 15). Although the hardness is higher at these sites and provides a higher acute TVS standard, concentrations of aluminum and copper are at least an order of magnitude above the table value standards.

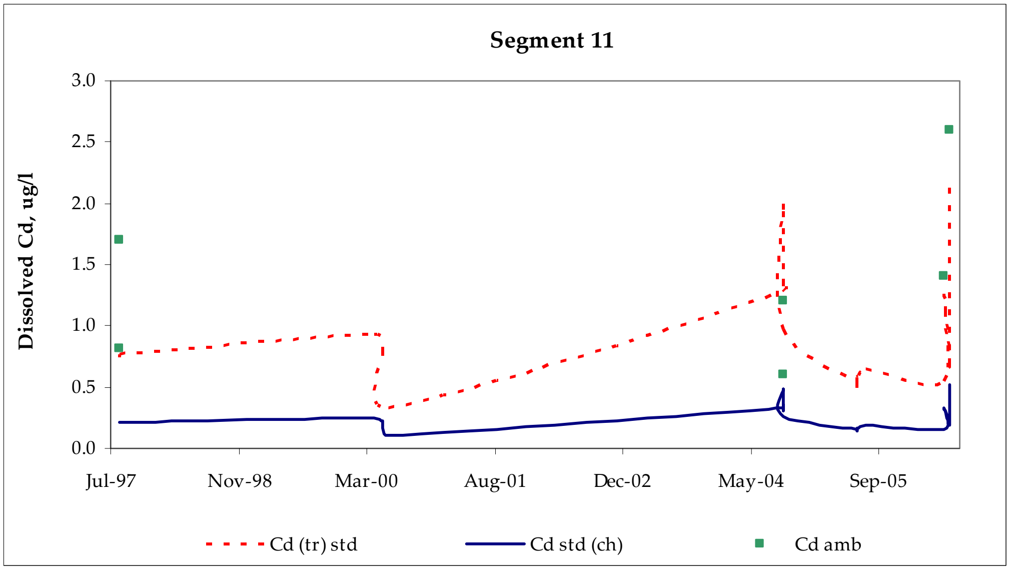
WQCD Site	Al-D % Reduction	Cd-D % Reduction	Cu-D % Reduction	Zn-D % Reduction
S. Fork Lake Creek Upstream Sayres Gulch	74%	48%	90%	45%
S. Fork Lake Creek Below Sayres Gulch	74%	0%	98%	4%
Sayres Gulch Above Confluence with Lake Creek	98%	84%	100%	67%
E. Fork Sayres Gulch Upstream W. Fork Sayres Gulch	97%	73%	99%	69%
W. Fork Sayres Gulch Upstream E. Fork Sayres Gulch	--	--	90%	0%
Annual	98%	81%	100%	57%

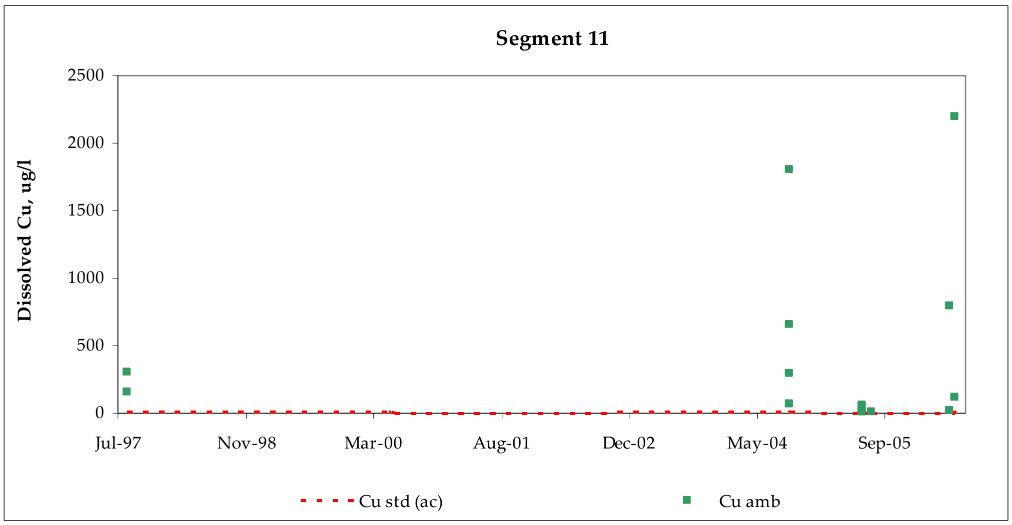
Table 16. Percent reductions in concentration of dissolved aluminum, dissolved cadmium, dissolved copper, and dissolved zinc in Segment 11, Sayres Gulch, in the Upper Arkansas River basin needed to attain table value standards.

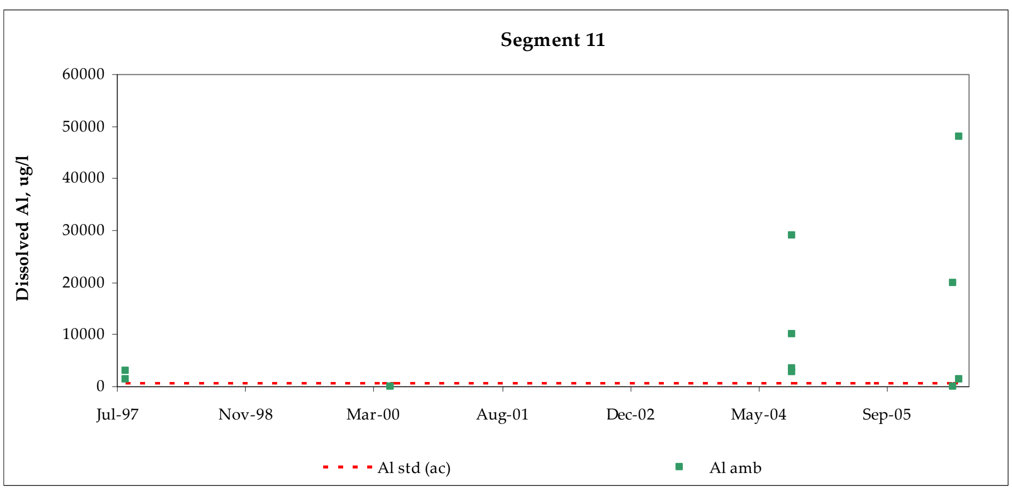
Instream pH values drop below the minimum pH standard of 6.5 s.u. at three out of the five sample sites. When the data is compiled, instream pH values remain at 4.6 s.u., which is below the minimum allowable value. The two sites that are in attainment of the pH standard are the South Fork Lake Creek upstream of Sayres Gulch and the West Fork Sayres Gulch upstream of East Fork Sayres Gulch (Table 15).

Copper would require the largest annual reduction of almost 100% (98%) in order to attain current acute standards; while aluminum would require the second largest annual reduction of 98% (Table 16). Aluminum and copper reductions are greatest at the sites on Sayres Gulch above the confluence with Lake Creek and on the East Fork of Sayres Gulch upstream of the West Fork Sayres Gulch (Table 16). Reductions in cadmium concentrations are more uniform across sampling sites in Sayres Gulch, and would require an annual 81% reduction to meet its TVS standard (Table 16). Reductions in zinc concentrations are localized on the South Fork Lake Creek in addition to the sites Sayres Gulch above the confluence with Lake Creek and on the East Fork of Sayres Gulch upstream of the West Fork Sayres Gulch (Table 16). An annual 57% reduction in concentration would bring Sayres Gulch into attainment of the chronic zinc standard (Table 16).

Since Segment 11 is cold water stream, and given no habitat limitations, trout would be likely to occur throughout the segment. Four out of seventeen cadmium samples exceeded the acute cadmium trout standard (24%) (Figure 20). Segment 11 exceeded the acute copper standard in all samples but two (n=16). Acute aluminum standards were exceeded in nine of the thirteen samples (69%), while zinc concentrations exceeded acute standards in eight of the nineteen samples (42%).


Segment 11
Dissolved Cd, ug/l
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jul-97
Nov-98
Mar-00
Aug-01
Dec-02
May-04
Sep-05
Cd (tr) std
Cd std (ch)
Cd amb


Segment 11
Dissolved Cu, ug/l
2500
2000
1500
1000
500
0
Jul-97
Nov-98
Mar-00
Aug-01
Dec-02
May-04
Sep-05
Cu std (ac)
Cu amb


Segment 11
Dissolved Al, ug/l
60000
50000
40000
30000
20000
10000
0
Jul-97
Nov-98
Mar-00
Aug-01
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Sep-05
Al std (ac)
Al amb

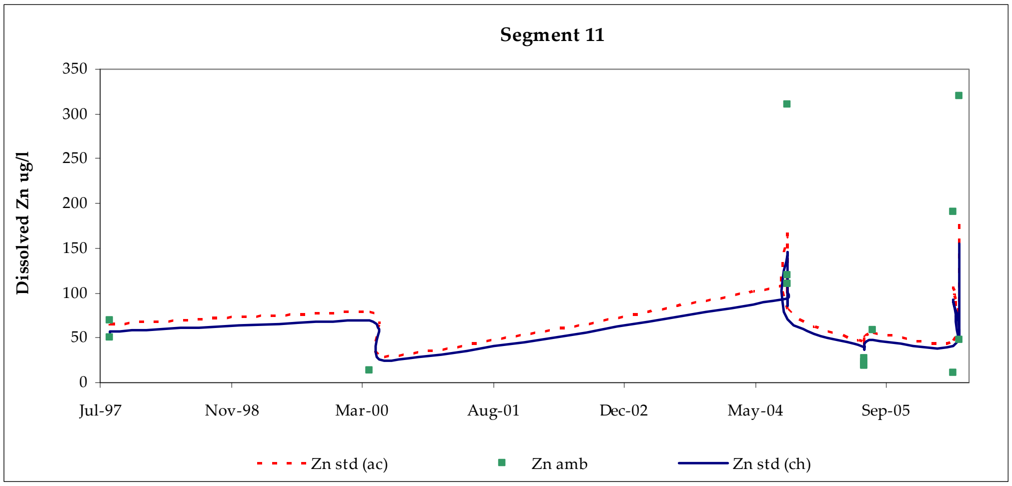


Figure 20. Acute (red dashed line) and chronic (blue solid line) standards for dissolved cadmium, copper, aluminum and zinc in Segment 11 of the Upper Arkansas River Basin. Green squares indicate sample concentrations.

The Colorado Geological Survey (CGS now DRMS) conducted a NASA-funded survey of the Lake Creek watershed (Segment 11) in Spring of 2002 through Fall 2003. The survey used remote sensing to map the mineralogy related to water quality within the hydrothermally altered watershed and to identify the relative contributions of natural and anthropogenic sources of metals contamination (Bird and Sares et al., 2003). Historic mining in the area was limited to only a few small claims, which were known for relatively low producing but high-grade gold deposits, none of which are known to discharge to the watershed. Production generally came from small, Laramide gold veins in Precambrian igneous rocks (Moran and Wentz, 1974). The watershed is an area of widespread hydrothermal alteration that includes pyrite, various clay minerals, iron oxides, and other minerals associated with acid-sulfate alteration. Springs discharging from this zone typically have pH below 3 and contain high concentrations of metals, including aluminum and iron exceeding 200 mg/L, copper up to 10 mg/L, and sulfate up to 29,000 mg/L (Bird and Sares et al., 2003). Hence, the area provides a unique opportunity to study the impacts from acid rock drainage (ARD) derived from primarily natural sources with only minimal anthropogenic disturbance (Bird and Sares et al., 2003). Previous survey work has identified the South Fork as the primary source of acid and metal loadings in the Lake Creek basin. Significant dilution from the North Fork greatly reduces downstream metals concentrations.

In Segment 12a (Chalk Creek), zinc exceeded the standard in every month below the influence of the Mary Murphy Mine (Table 17). Zinc concentrations were highest at the sites downstream of the North Fork Chalk Creek and the Mary Murphy Mine coinciding with the lowest stream hardness values (Table 17). Concentrations of zinc do, however, attain table value standards at the mouth, above the confluence with the Arkansas River in every month except May, which is indicative of very low hardness and resulting chronic standard (Table 17).

	Chalk Creek below Mine Influence				Chalk Creek @ Mouth above Mainstem Arkansas River		
	Avg. Hardness	Zn-D, TVS	Zinc, Dissolved	% Reduction	Avg. Hardness	Zn-D, TVS	Zinc, Dissolved
Jan	47	65.3	**243**	73%	56	75.8	18.0
Feb	47	65.3	**198**	67%	53	72.4	15.0
Mar	39	55.7	**189**	71%	60	80.4	14.0
Apr	31	45.8	**181**	75%	67	88.4	17.0
May	23	35.5	**101**	65%	31	45.8	**57.8**
Jun	26	39.4	**110**	64%	40	56.9	52.9
Jul	47	65.3	**120**	46%	47	65.3	37.5
Aug	48	66.5	**273**	76%	53	72.4	22.0
Sep	49	67.7	**426**	84%	69	90.6	22.3
Oct	49	67.7	**380**	82%	70	91.7	18.1
Nov	48	66.5	**334**	80%	71	92.8	14.0
Dec	48	66.5	**289**	77%	58	78.1	12.0
Annual	35	50.8	**315**	84%	54	73.5	51.8

Table 17. Percent reductions in concentration of dissolved zinc in Segment 12a, Chalk Creek, in the Upper Arkansas River basin needed to attain table value standards.

Chalk Creek would require an annual reduction in stream concentration of 84% below the Mary Murphy Mine influence in order to attain chronic zinc standards. The highest zinc reductions occur during low flow months (September-November) and range from 80% to 84% (Table 17). The lowest reductions in zinc concentrations occurred in July, with a 46% reduction required in order to attain chronic zinc standards (Table 17). Contrary to zinc reductions, the highest required reductions in lead concentrations would take place during spring runoff, May and June (Table 18). May and June were the only months with measurable lead concentrations. Due to the extremely low hardness values, TVS values are also extremely low. Lead concentrations would need to be reduced by 42% in May and 83% in June in order to meet table value standards (Table 18).

	Chalk Creek below Mine Influence				Chalk Creek @ Mouth above Mainstem Arkansas River		
	Avg. Hardness	Pb-D, TVS	Lead, Dissolved	% Reduction	Avg. Hardness	Pb-D, TVS	Lead, Dissolved
Jan	47	1.1	0.0	0%	56	1.3	0.0
Feb	47	1.1	0.0	0%	53	1.3	0.0
Mar	39	0.9	0.3	0%	60	1.4	0.0
Apr	31	0.7	0.6	0%	67	1.6	0.0
May	23	0.5	**0.9**	42%	31	0.7	0.9
Jun	26	0.6	**3.3**	83%	40	0.9	1.7
Jul	47	1.1	0.0	0%	47	1.1	0.9
Aug	48	1.1	0.0	0%	53	1.3	0.0
Sep	49	1.2	0.0	0%	69	1.7	0.0
Oct	49	1.2	0.0	0%	70	1.7	0.0
Nov	48	1.1	0.0	0%	71	1.7	0.0
Dec	48	1.1	0.0	0%	58	1.4	0.0
Annual	35	0.8	0.5	0%	54	1.3	0.8

Table 18. Percent reductions in concentration of dissolved lead in Segment 12a, Chalk Creek, in the Upper

Arkansas River basin needed to attain table value standards.

Fifteen out of twenty-seven zinc samples exceeded the acute trout standard (56%) (Figure 21). Of the fifteen acute standard exceedances, three (20%) of the exceedances occurred at the mouth of Chalk Creek above the confluence with the Arkansas River. The remaining twelve exceedances occurred upstream of the mouth but still below the Mary Murphy Mine. There were no exceedances of the acute lead standard in Segment 12a.

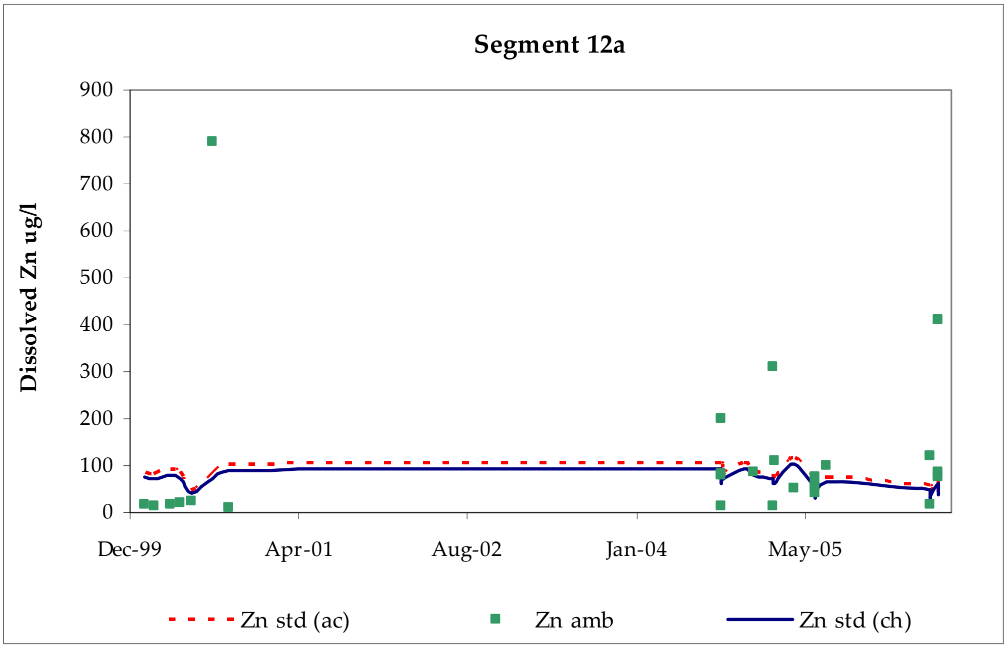


Figure 21. Acute (red dashed line) and chronic (blue solid line) standards for dissolved zinc in Segment 12a of the Upper Arkansas River Basin. Green squares indicate sample concentrations.

VII. SOURCES, TECHNICAL ANALYSIS, AND TMDL LOAD ALLOCATIONS

The vast majority of the metal loads into the Arkansas River basin are from historic mining activities. The metal loads to the Arkansas River vary along the length of the stream, and correspondingly so do the ambient concentrations of metals. Additionally there are 13 permitted dischargers within the upper Arkansas River watershed (Table 2).

For most of the stream segments, the highest metal loads occurred during both high and low flow periods, and in all cases hardness values fluctuated seasonally as well (Tables 19-30). Exceedances of stream standards are also likely to occur during periods of low flow when there is less dilution available, or in spring when snowmelt infiltrates shallow aquifers displacing metal-laden water stored within the aquifer to adjacent streams, but it should be noted that exceedances of the standards occurred at all times of the year.

7.1 Total Maximum Daily Loads (TMDL)

A TMDL is comprised of the Load Allocation (LA), which is that portion of the pollutant load attributed to natural background or the non-point sources, the Waste Load Allocation (WLA), which is that portion of the pollutant load associated with both permitted and non-permitted point source discharges, and a Margin of Safety (MOS). The TMDL may be expressed as the sum of the LA, WLA and MOS.

TMDL = WLA + LA + MOS

TMDL = Sum of Waste Load Allocations + Sum of Load Allocations + Margin of Safety

Waste Load Allocations "(WLA)"

There are thirteen identified permitted dischargers actively discharging to listed segments in the upper Arkansas River watershed. In addition to these permitted discharges, historic effects from the combination of mining activities and natural geologic conditions, however, are treated as non-permitted point sources in all segments of this TMDL.

Load Allocations "(LA)"

Remaining background sources that were examined are considered non-point sources and are therefore accountable to load allocations. Since the watershed of Segment 11 is an area of widespread hydrothermal alteration that includes pyrite, various clay minerals, iron oxides, and other minerals associated with acid-sulfate alteration, it is also considered to be attributable to natural background. Springs discharging from this zone typically have pH below 3 and contain high concentrations of metals, including aluminum and iron exceeding 200 mg/L, copper up to 10 mg/L, and sulfate up to 29,000 mg/L (Bird and Sares et al., 2003). Therefore, the impacts from acid rock drainage (ARD) derived from primarily natural sources with only minimal anthropogenic disturbance (Bird and Sares et al., 2003) are considered to be a non-point source and are given a load allocation in the TMDL.

Margin of Safety "(MOS)"

According to the Federal Clean Water Act, TMDLs require a margin of safety (MOS) component that accounts for the uncertainty about the relationship between the pollutant loads and the receiving waterbody. The MOS can be implicit or explicit. An implicit margin of safety was included in this TMDL. This MOS is included to account for the uncertainty in the analysis of the relationship between the TMDL loading allocations and the desired water quality target.

The TMDL was calculated using a monthly median flow multiplied by the existing stream standard and a conversion factor (0.0054) to approximate a load in pounds/day. Ambient stream loads were approximated by multiplying 95th percentile metals concentrations by median flows (monthly or annual, where applicable). This also ensures that reductions necessary to attain chronic standards will also ensure attainment of acute standards. Use of annual minimum hardness values in conjunction with maximum observed metals concentrations were applied to stream segments with only acute standards. By incorporating the critical condition into the calculation of the TMDL, load reductions tend to be overestimated. The incorporation of monthly TMDLs reflects the seasonality of metals load reductions in the upper Arkansas River basin and more adequately reflects the current water quality situation.

When WQBELs were used in waste load allocations, acute and chronic low flows were calculated using USEPA DFLOW software. Acute (1E3) and chronic (30E3) flows are biologically based low flows. Biologically-based design flows are intended to measure the actual occurrence of low flow events with respect to both the duration and frequency (i.e., the number of days aquatic life is subjected to flows below a certain level within a period of several years). Although the extreme value analytical techniques used to calculate hydrologically-based design flows have been used extensively in the field of hydrology and in state water quality standards, these methods do not capture the cumulative nature of effects of low flow events because they only consider the most extreme low flow in any given year. By considering all low flow events with a year, the biologically-based design flow method accounts for the cumulative nature of the biological effects related to low flow events. Acute low flows (1E3) refer to single low flow events that occur once in a three year period. Chronic low flows (30E3) refer to 30-day low flow periods which occur once in three years.

Metal loads from dischargers were calculated using the design capacity for flow, and the effluent limits listed in their current permit. Where no limits were given, the limit was assumed to be equal to the stream standard. Modeled discharges were then given waste load allocations (WLA). In order to determine WLAs for abandoned mine sources, stream background concentrations were calculated upstream of mine influence. Increases in stream concentrations after contact with residual mine influences was attributed to abandoned mine sources, and a percent contribution to the stream load was calculated. Load allocations (LA) were then calculated by subtracting the total of the WLAs from the TMDL. Where the ambient stream load was higher than the TMDL a load reduction was calculated.

Segment 2b

Since the adoption of site-specific standards for cadmium and zinc in the summer of 2007, the months that do not meet the TMDL load allocation have been significantly reduced in Segments 2b and 2c. In the mainstem Arkansas River from California Gulch to Lake Fork (Segment 2b) the highest cadmium loading occurred in the months during and following spring runoff, April-May and July-September (Table 19). Consequently, the largest load reductions (lbs/day) also fall in the months of April, May and July (71%, 66% and 69%, respectively). The months of June and October-March are currently attaining their site specific dissolved cadmium standard, and no load reductions are required. The same loading pattern is true for zinc. The highest zinc loading reductions occur in April and July, with reductions of 61%, and 64%, respectively, in order to attain site-specific stream standards (Table 20). The months of October-March are also currently in attainment of the zinc standard. The two permitted facilities on Segment 2b contribute only a small percentage of the total metals load to the stream.

A load duration curve was developed to further assess dissolved cadmium and zinc loads in Segment 2b of the mainstem Arkansas River (Figure 22). Ambient water quality data which was taken with some measure of flow at the time of sampling was used to compute an instantaneous load. By displaying instantaneous loads calculated from ambient water quality and the daily average flow on the date of the sample (expressed as a flow duration curve interval), a pattern develops, which describes the characteristics of the water quality impairment. Loads that plot above the curve indicate an exceedance of the water quality criterion, while those below the load duration curve show compliance.

Cadmium - Segment 2b - 95th% and Median Flows

	WLA, lbs/day

Month	TMDL, lbs/day	Total Discharger WLA, lbs/day	Abandoned Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL	Butala Construction	Lake Fork Mobile Home Park
Jan	0.152	0.0021	0.135	0.015	0.07	-0.08	0%	0.002	0.0001
Feb	0.141	0.0021	0.125	0.014	0.04	-0.10	0%	0.002	0.0001
Mar	0.156	0.0021	0.139	0.015	0.07	-0.09	0%	0.002	0.0001
Apr	0.223	0.0021	0.199	0.022	0.78	0.55	71%	0.002	0.0001
May	0.790	0.0021	0.709	0.079	2.33	1.54	66%	0.002	0.0001
Jun	1.406	0.0021	1.263	0.140	1.07	-0.34	0%	0.002	0.0001
Jul	1.042	0.0021	0.936	0.104	3.36	2.32	69%	0.002	0.0001
Aug	0.466	0.0021	0.417	0.046	0.60	0.14	23%	0.002	0.0001
Sep	0.340	0.0021	0.304	0.034	0.48	0.14	28%	0.002	0.0001
Oct	0.253	0.0021	0.226	0.025	0.10	-0.16	0%	0.002	0.0001
Nov	0.200	0.0021	0.178	0.020	0.14	-0.06	0%	0.002	0.0001
Dec	0.200	0.0021	0.178	0.020	0.12	-0.08	0%	0.002	0.0001

Table 19. Cadmium total maximum daily load, waste load allocation, and load allocations for Segment 2b (mainstem Arkansas River from California Gulch to Lake Fork). Stream loads are given for dissolved cadmium, waste loads are given for potentially dissolved cadmium. TMDL and current stream loads are based on median flows for the Arkansas below Leadville and 95th percentile monthly dissolved cadmium concentrations.

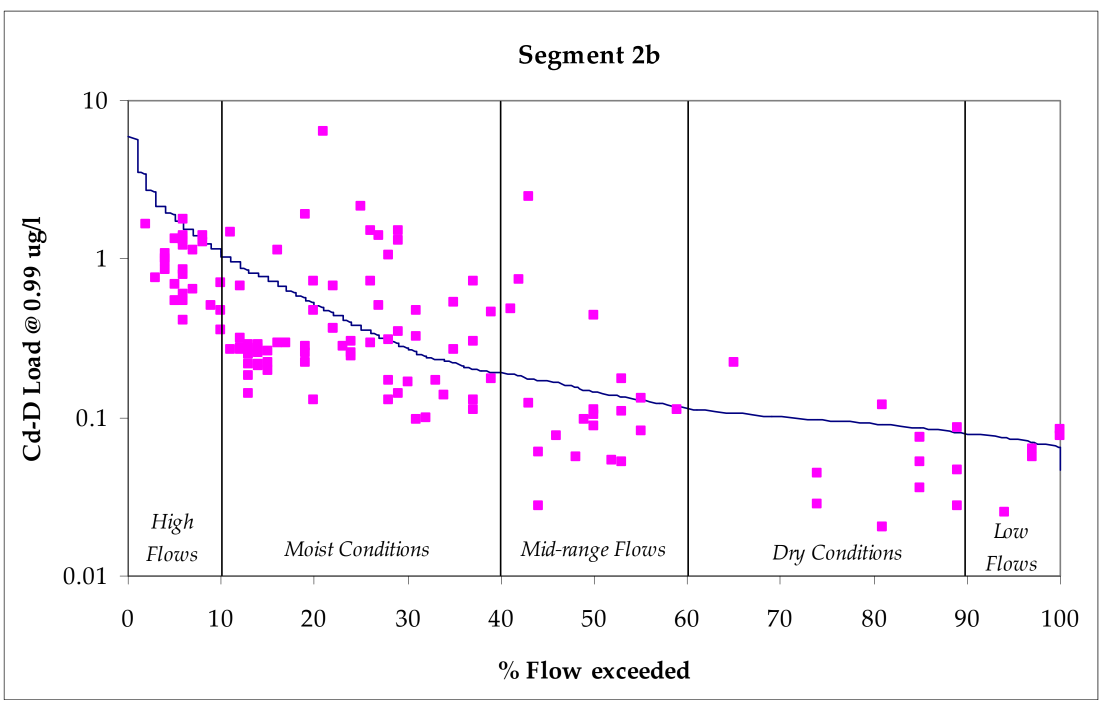
Zinc - Segment 2b - 95th% and Median Flows									
								WLA, lbs/day	
Month	TMDL, lbs/day (Median Flow)	Total Discharger WLA, lbs/day	Abandoned Mine WLA, lbs/day	Total LA, lbs/day	Avg. Stream Load, lbs/day (Median Flow)	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL	Butala Construction	Lake Fork Mobile Home Park
Jan	40.2	1.1	35.2	3.9	29.8	-10.38	0%	1.025	0.0371
Feb	37.3	1.1	32.6	3.6	18.4	-18.91	0%	1.025	0.0371
Mar	41.5	1.1	36.4	4.0	23.0	-18.55	0%	1.025	0.0371
Apr	57.9	1.1	51.1	5.7	147.3	89.37	61%	1.025	0.0371
May	196.9	1.1	176.3	19.6	311.7	114.75	37%	1.025	0.0371
Jun	340.3	1.1	305.3	33.9	230.2	-110.15	0%	1.025	0.0371
Jul	273.4	1.1	245.1	27.2	761.5	488.10	64%	1.025	0.0371
Aug	122.1	1.1	108.9	12.1	172.6	50.51	29%	1.025	0.0371
Sep	90.7	1.1	80.7	9.0	154.1	63.41	41%	1.025	0.0371
Oct	66.6	1.1	59.0	6.6	38.3	-28.28	0%	1.025	0.0371
Nov	52.3	1.1	46.1	5.1	47.7	-4.56	0%	1.025	0.0371
Dec	53.9	1.1	47.6	5.3	41.9	-11.99	0%	1.025	0.0371

Table 20. Zinc total maximum daily load, waste load allocation, and load allocations for Segment 2b (mainstem Arkansas River from California Gulch to Lake Fork). Stream loads are given for dissolved zinc, waste loads are given for potentially dissolved zinc. TMDL and current stream loads are based on median flows for the Arkansas below Leadville and 95th percentile monthly dissolved zinc concentrations.

As indicated by Figure 22, exceedances of the cadmium and zinc standards were most prevalent during periods of higher flow conditions. Therefore, moist conditions, or the period bracketing spring runoff, represent the critical condition in Upper Arkansas Segment 2b. Consequently, ambient stream loads were calculated using median flows and ninety-fifth percentile metals concentrations which incorporate an implicit margin of safety into the TMDL calculations.

The pattern of impairment was then examined to see if it occurred across all flow conditions, corresponded strictly to high flow events, or conversely, only to low flows. Impairments observed in the low flow zone typically indicate the influence of point sources, while those further left generally reflect potential non-point source contributions. In the case of Figure 22, data is allocated into differing flow conditions. Flow curves represent allowable loads at an annual cadmium standard of 0.99 µg/l. As demonstrated by the curve, dissolved cadmium concentrations often exceed the standard during moist conditions. Cadmium concentrations are typically in attainment during dry conditions and low flows. Concentrations during periods of mid-range flows also exceed the standard. Zinc load followed the same flow patterns as cadmium, with most exceedances occurring during moist conditions and mid-range flows. During dry conditions to extreme low flows, however, exceedances occurred almost 50% of the time (6 out of 13 samples) (Figure 22).

After the TMDL was calculated, monthly chronic load reductions were applied to sampled values to determine attainment of the acute trout standard. An additional 33% reduction in the month of May would be required to attain its acute trout standard, due to a sample value of 13.85 µg/L in May of 2002. Similarly, an additional 3% reduction in July and an 8% reduction in August are also necessary. One acute exceedance in June would need a 60% reduction in order to attain its acute cadmium standard. An additional zinc reduction of 18% in May would bring May acute standards into attainment. Additionally, 3% in July and 2% in August would alleviate acute zinc exceedances in these months. If these reductions were attained, Upper Arkansas Segment 2b would be in attainment of its acute and chronic cadmium and zinc standards.



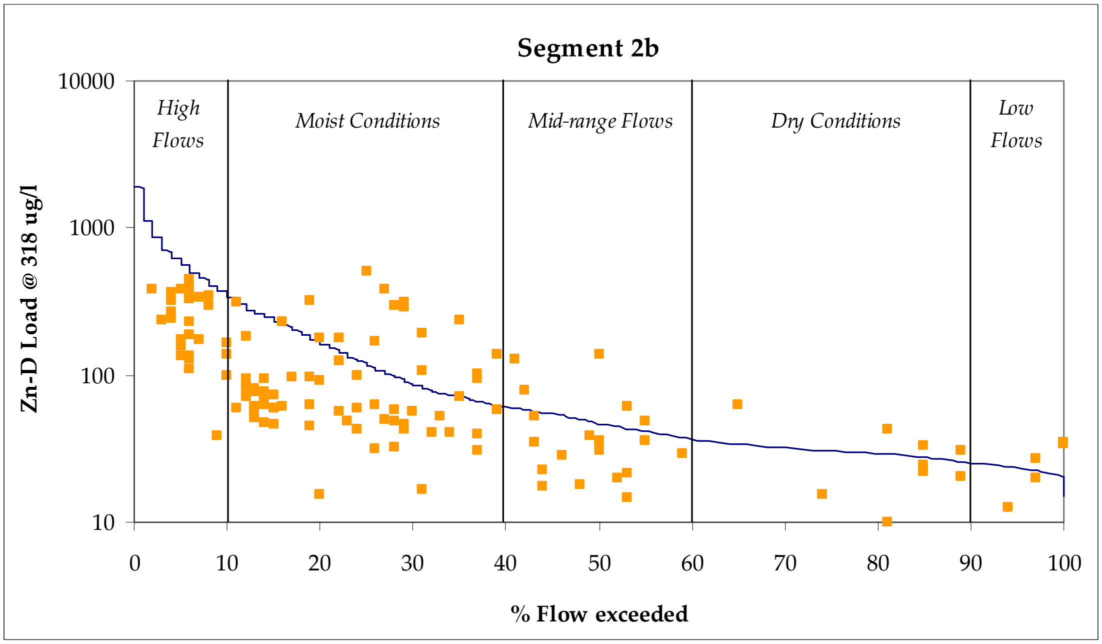


Figure 22. Flow duration curves for dissolved cadmium and zinc loads for Upper Arkansas Segment 2b. The load duration curve approximates the cadmium load of an annual Cd-D standard of 0.99 µg/L and Zn-D standard of 318 µg/l.

Segment 2c

In Segment 2c, the mainstem Arkansas River from the Lake Fork to Lake Creek, the highest cadmium loading occurs during spring runoff in May and June. When the critical condition is assessed, the highest, and subsequently, the only load reduction also corresponds to spring runoff (14%) (Table 21). Similar to cadmium, significant zinc loading also occurs in the months of May and June, corresponding with spring runoff and higher flows. Currently, the month of May is also the only month to require a zinc load reduction at 9%, (Table 22). The one permitted facility on Segment 2c contributes only a small percentage of the zinc load to the stream (Figure 23).

Figure 23 illustrates the average annual contribution from the different sources: point source dischargers, abandoned mine activity (non-permitted point sources), and non-point sources, or natural background. The waste load allocation for permitted dischargers remains constant throughout the year; however their contribution to the annual load varies by month. On an annual basis, non-permitted point sources (abandoned mines, 87%) and permitted dischargers (3%) contribute a total percentage of approximately 90% to the annual cadmium load in the mainstem Arkansas River from Lake Fork to Lake Creek (Figure 23). Non-point sources, or natural background sources, account for approximately 10% of the average annual cadmium load (Figure 23). This same approximate contribution is true for both cadmium and zinc in upper Arkansas Segments 2b and 2c.

As demonstrated in Figure 24, data was allocated into differing flow conditions. Flow curves represent allowable loads at an annual cadmium standard of 0.80 µg/l. As demonstrated by the curve, dissolved cadmium concentrations rarely exceed the standard. Exceedances are, however, more prevalent during high flows and moist conditions. Only three exceedances occurred during dry conditions and low flows. Zinc loads followed the same flow patterns as cadmium, with only one exceedance occurring during moist conditions. During all remaining flow regimes, the zinc allowable load is attained (Figure 24).

Cadmium - Segment 2c - 95th% and Median Flows								
								WLA, lbs/day
Month	TMDL, lbs/day	Total Discharger WLA, lbs/day	Abandoned Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL	CDOW Fish Hatchery
Jan	0.113	0.002	0.100	0.011	0.032	-0.080	0%	0.002
Feb	0.106	0.002	0.093	0.010	0.024	-0.082	0%	0.002
Mar	0.109	0.002	0.096	0.011	0.035	-0.074	0%	0.002
Apr	0.158	0.002	0.140	0.016	0.131	-0.027	0%	0.002
May	0.583	0.002	0.522	0.058	0.674	0.091	14%	0.002
Jun	1.406	0.002	1.264	0.140	0.617	-0.789	0%	0.002
Jul	0.695	0.002	0.623	0.069	0.159	-0.536	0%	0.002
Aug	0.336	0.002	0.301	0.033	0.193	-0.143	0%	0.002
Sep	0.235	0.002	0.210	0.023	0.052	-0.183	0%	0.002
Oct	0.181	0.002	0.161	0.018	0.095	-0.086	0%	0.002
Nov	0.147	0.002	0.131	0.015	0.043	-0.105	0%	0.002
Dec	0.138	0.002	0.122	0.014	0.104	-0.034	0%	0.002

Table 21. Cadmium total maximum daily load, waste load allocations, and load allocations for Segment 2c (mainstem Arkansas River from Lake Fork to Lake Creek). Stream loads are given for dissolved cadmium, waste loads are given for potentially dissolved cadmium. Current stream loads are based on median flows for the Arkansas below Leadville and 95th percentile monthly dissolved cadmium concentrations. TMDL allowable loads are calculated using site-specific chronic dissolved cadmium standards and median flows.

Zinc - Segment 2c - 95th% and Median Flows								
								WLA, lbs/day
Month	TMDL, lbs/day	Total Discharger WLA, lbs/day	Abandoned Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL	CDOW Fish Hatchery
Jan	28.5	0.78	25.0	2.78	15.3	-13.2	0%	0.776
Feb	26.9	0.78	23.5	2.61	8.3	-18.6	0%	0.776
Mar	27.4	0.78	24.0	2.67	10.0	-17.4	0%	0.776
Apr	39.2	0.78	34.6	3.85	34.9	-4.4	0%	0.776
May	139.3	0.78	124.7	13.85	153.2	13.9	9%	0.776
Jun	340.4	0.78	305.6	33.96	192.0	-148.4	0%	0.776
Jul	173.1	0.78	155.1	17.23	49.6	-123.5	0%	0.776
Aug	84.2	0.78	75.1	8.34	29.0	-55.3	0%	0.776
Sep	59.7	0.78	53.1	5.89	17.4	-42.3	0%	0.776
Oct	45.7	0.78	40.4	4.49	14.9	-30.7	0%	0.776
Nov	37.3	0.78	32.8	3.65	10.5	-26.8	0%	0.776
Dec	35.4	0.78	31.2	3.47	13.8	-21.7	0%	0.776

Table 22. Zinc total maximum daily load, waste load allocations, and load allocation for

Segment 2c (mainstem Arkansas River from Lake Fork to Lake Creek). Stream loads are given for dissolved zinc, waste loads are given for potentially dissolved zinc. Current stream loads are based on median flows for the Arkansas below Leadville and 95th percentile monthly dissolved zinc concentrations. TMDL allowable loads are calculated using site-specific chronic dissolved zinc standards and median flows.

After the TMDL was calculated, monthly chronic load reductions were applied to sampled values to determine attainment of the acute trout standard. No additional reduction would be required to attain its acute trout standard. If chronic load reductions were attained, Upper Arkansas Segment 2c would be in attainment of its acute and chronic cadmium and zinc standards.

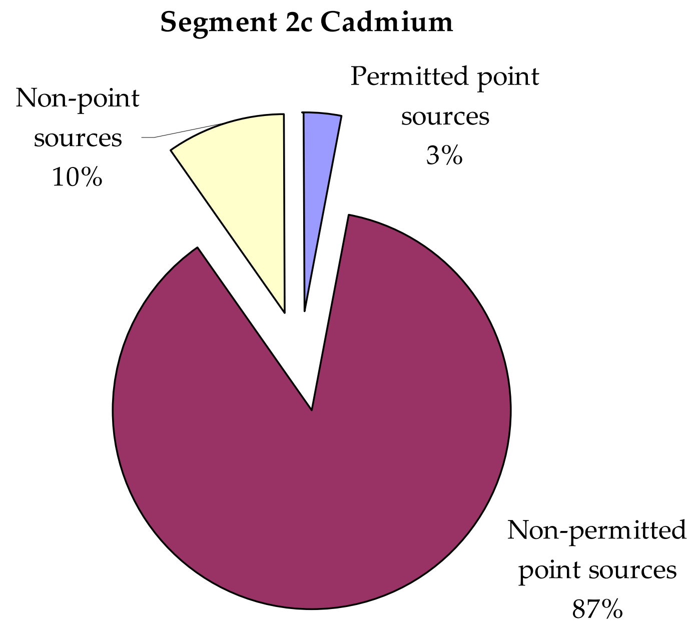
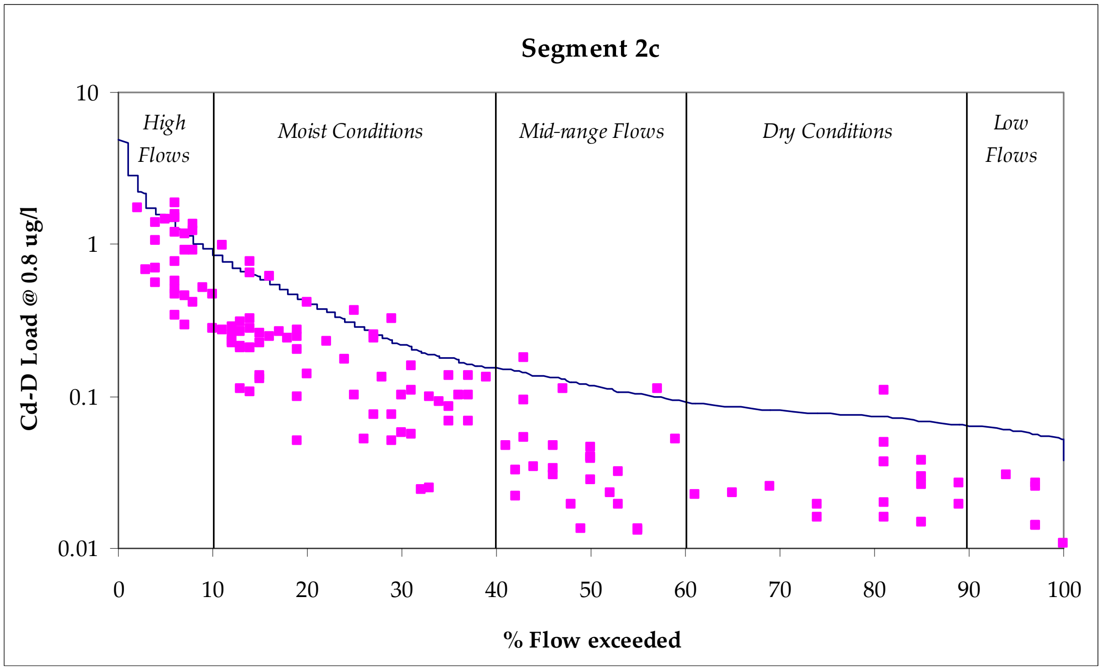


Figure 23. Pie graph of upper Arkansas, Segment 2c, annual average contribution to cadmium load is attributable to both point and non-point sources.



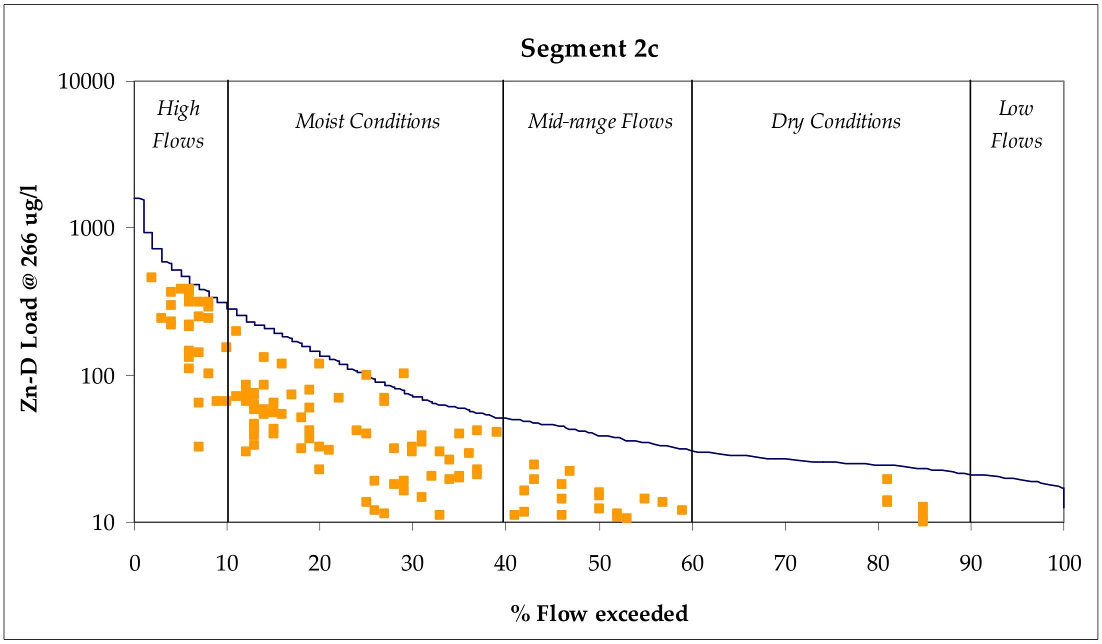


Figure 24. Flow duration curves for dissolved cadmium and zinc loads for Upper Arkansas Segment 2c. The load duration curve approximates the cadmium load of an annual Cd-D standard of 0.8 μg/L and Zn-D standard of 266 μg/l.

Segment 3

Segment 3 of the upper Arkansas River is a 150 mile long segment that extends from a point immediately above the Lake Creek confluence to the inlet to Pueblo Reservoir. Pursuant to Natural Resource Damage Claims filed on the upper Arkansas River, natural resource injuries were assessed for the upper Arkansas River downstream of the 11-Mile Reach (defined as segment 2c). Based on the characterization of the 11-Mile reach, surface water was identified as the fundamental contaminant transport mechanism and exposure pathway for the downstream area (SCR, 2002). The downstream area of the Arkansas River undergoes significant physical and chemical changes from the bottom of the 11-Mile reach to Pueblo Reservoir. The obvious impacts associated with the deposition of historic mine waste diminish over this same distance (SCR, 2002). The Site Characterization Report (SCR) of the Upper Arkansas River Basin document states “Based on review of both sediment and water quality studies, it appears that the most significant source of metals (primarily cadmium, copper, iron, lead, manganese, and zinc) to the Upper Arkansas River has been, and continues to be, the Leadville Mining District. Current levels of metals in the downstream area can be primarily be related to water quality in California Gulch.” Therefore, all of the metals loading for Segment 3 (cadmium, lead and zinc) are treated as non-point sources, or natural background, and are given load allocations.

Downstream on the mainstem in Segment 3 (mainstem Arkansas River from Lake Creek to the inlet to Pueblo Reservoir), only four months of the year (July-September and November) currently meet the TMDL loading allocations for cadmium (Table 23). During the remaining months of the year, cadmium load reductions range from 17% to 75%, with the highest required load reductions occurring during the onset of runoff, May (75%), and the months of February (63%) and March (55%) (Table 23). The largest cadmium load occurs in May, corresponding to the highest required load reduction (Table 23). Cadmium load reductions remain between 0 and 54% for the remainder of the year.

Segment 3 does not meet current lead loading allocations in the months of March-May and August-September (Table 24). The highest loading occurs in May and August, during the rising and falling limbs of the hydrograph, requiring 64% and 72% reductions, respectively. Lead load reductions remain between 0 and 38% for the remainder of the year.

Upper Arkansas Segment 3 also does not meet zinc loading allocations for five months of the year (Table 25). No zinc load reductions are required in February-March and August-December. Similar to cadmium, the highest zinc loading occurs during periods of high stream flow (May and June) corresponding with the highest required load reductions of 65% and 35%, respectively (Table 25). Load reductions in the remaining months range from 0 to 22% in April (Table 25). If chronic load reductions are achieved for the three listed metals in Segment 3, acute standards will also be attained.

Similar to Segments 2b and 2c, a load duration curve was developed to further assess dissolved metals loads in Segment 3 of the mainstem Arkansas River (Figure 24). Ambient water quality data which was taken with some measure of flow at the time of sampling was used to compute an instantaneous load. By displaying instantaneous loads calculated from ambient water quality and the daily average flow on the date of the sample (expressed as a flow duration curve interval), a pattern develops, which describes the characteristics of the water quality impairment. Loads that plot above the curve indicate an exceedance of the water quality criterion, while those below the load duration curve show compliance. The six routine sampling sites along Segment 3 were given unique data labels to identify them on the load duration curves.

The site, Arkansas at Kobe, demonstrates the most exceedances of the cadmium standard most often during periods of high flow, moist conditions, and dry conditions (Figure 24). Additionally, exceedances of the cadmium standard were observed most frequently at the sites, Arkansas River at Union Hill Mill and the Arkansas River at Granite (Figure 24).

As demonstrated by the load duration curve for lead, in general, fewer exceedances of the lead standard occurred (Figure 24). Exceedances of the standard occurred during all flow regimes most often at the sites: Arkansas River at Cotopaxi, Union Hill Mill, and Granite (Gage) (Figure 24).

Exceedances of the zinc standard were more concentrated during high flow periods and moist conditions at the sites: Arkansas River at Kobe and Cotopaxi. Exccedances during mid-range flows and drier conditions were typically observed at the Arkansas River at Kobe with additional exceedances occurring at the Otero Pump Station and Arkansas River at Granite (Figure 24).

Due to the length of Segment 3, loading allocations were plotted along the length of the segment. Cadmium loading demonstrates the highest cadmium load occurring at the most upstream site, Arkansas River at Kobe, with a load of 252 lbs/year (Figure 25). Lead loading remained below 1000 lbs/year along the length of the segment until the WQCD sampling site near Johnson's Village. The highest lead load occurred at the site Arkansas River at Salida, with an annual load of 4876 lbs/year (Figure 25). Zinc loading appears to happen similar to cadmium with the highest zinc load occurring at the most upstream site, Arkansas River at Kobe, with a load of 76,305 lbs/year (Figure 25). Zinc loads are decreased significantly during periods of chronic low flow, with a maximum of 20,368 lbs year occurring at the Arkansas River at Kobe (Figure 25).

Segment 5

In Segment 5, Halfmoon Creek, the chronic dissolved cadmium and lead loads do not meet the current TMDL loading allocations. The TMDL and current stream load were based on median flows and 95th percentile instream metals concentrations. During median flow periods, the cadmium load averages 13 lbs/year at Halfmoon Creek below North Fork Halfmoon Creek and 82 lbs/year at Halfmoon Creek near Leadville. During periods of median flow, the total lead load is approximately 145 lbs/year at Halfmoon Creek below North Fork Halfmoon Creek. However, the lead load at Halfmoon Creek near Leadville increases to almost 268 lbs/year. Although mining activity in the Halfmoon Creek basin is considered to be less than in other drainages in the upper Arkansas River Basin, significant load reductions are still required for both cadmium and lead. Based on differences in upstream and downstream concentrations, 80% of the cadmium load is attributable to the influence of abandoned mine sources. A 74 % reduction in the cadmium load is required at the site Halfmoon Creek below North Fork Halfmoon Creek in order to attain chronic cadmium standards. A 96% cadmium load reduction is required at the site Halfmoon Creek near Leadville. Ninety-five percent of the lead load is attributable to abandoned mine sources in the watershed. The current lead load would need to be reduced by approximately 91% at Halfmoon Creek below North Fork Halfmoon Creek in order to meet the TMDL loading allocations and 95% at Halfmoon Creek near Leadville (Table 26).

Cadmium - Segment 3- 95th% and Median Flows													
							WLA, lbs/day						
Month	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Exisitng Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL	Buena Vista Sanitation District	Salida WWTF	Heart of the Rockies Regional Med. Center	Jesse Lee Pit	Med. Center Replacement Hosp.	Mt. Shavano Fish Hatchery
Jan	0.83	0.027	0.80	1.08	0.25	23%	0.006	0.005	0.002	N/A	0.0003	0.015
Feb	0.75	0.027	0.73	2.06	1.31	63%	0.006	0.005	0.002	N/A	0.0003	0.015
Mar	0.68	0.027	0.65	1.53	0.85	55%	0.006	0.005	0.002	N/A	0.0003	0.015
Apr	0.61	0.027	0.58	1.12	0.51	46%	0.006	0.005	0.002	N/A	0.0003	0.015
May	1.07	0.027	1.04	4.20	3.13	75%	0.006	0.005	0.002	N/A	0.0003	0.015
Jun	2.13	0.027	2.10	3.56	1.43	40%	0.006	0.005	0.002	N/A	0.0003	0.015
Jul	1.26	0.027	1.24	1.19	-0.07	0%	0.006	0.005	0.002	N/A	0.0003	0.015
Aug	1.25	0.027	1.23	1.23	-0.03	0%	0.006	0.005	0.002	N/A	0.0003	0.015
Sep	0.80	0.027	0.77	0.68	-0.12	0%	0.006	0.005	0.002	N/A	0.0003	0.015
Oct	0.79	0.027	0.76	0.95	0.16	17%	0.006	0.005	0.002	N/A	0.0003	0.015
Nov	0.85	0.027	0.82	0.69	-0.16	0%	0.006	0.005	0.002	N/A	0.0003	0.015
Dec	0.91	0.027	0.88	1.97	1.06	54%	0.006	0.005	0.002	N/A	0.0003	0.015

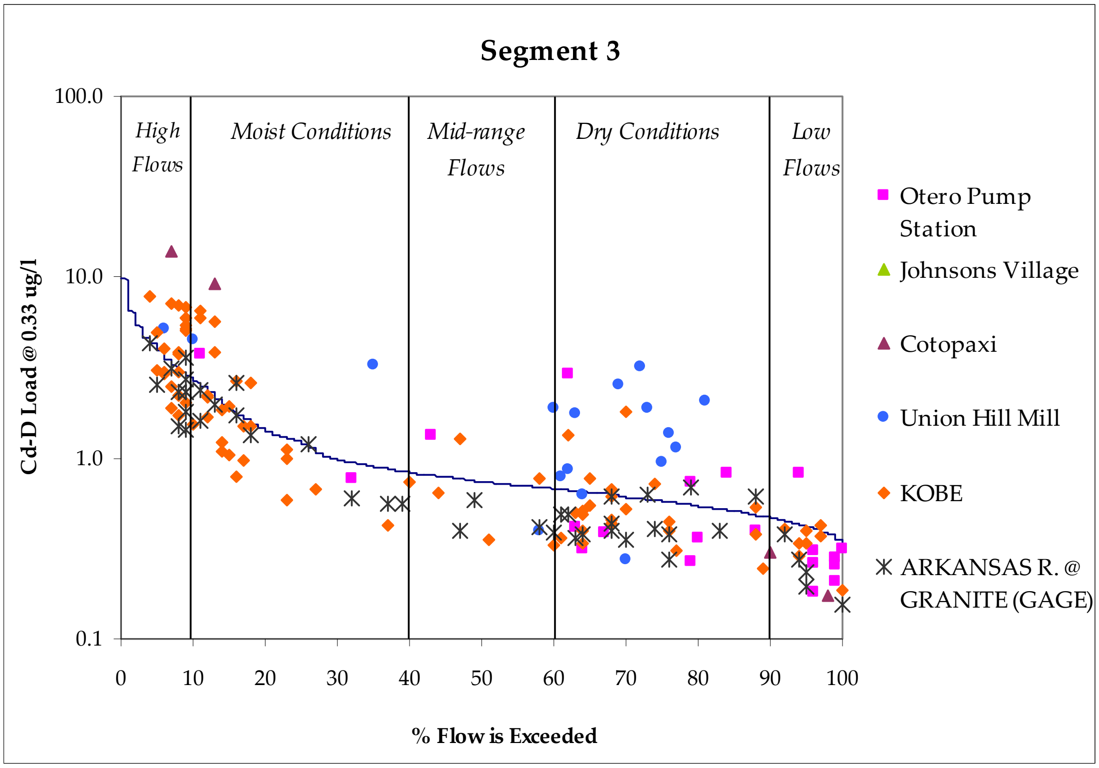
Table 23. Cadmium total maximum daily load, waste load allocation, and load allocations for Segment 3 (mainstem Arkansas River from Lake Creek to Badger Creek). Stream loads are given for dissolved cadmium, waste loads are given for potentially dissolved cadmium. Current stream loads are based on median flows for the Arkansas below Wellsville and 95th percentile monthly dissolved cadmium concentrations. TMDL allowable loads are calculated using chronic dissolved cadmium standards and median flows.

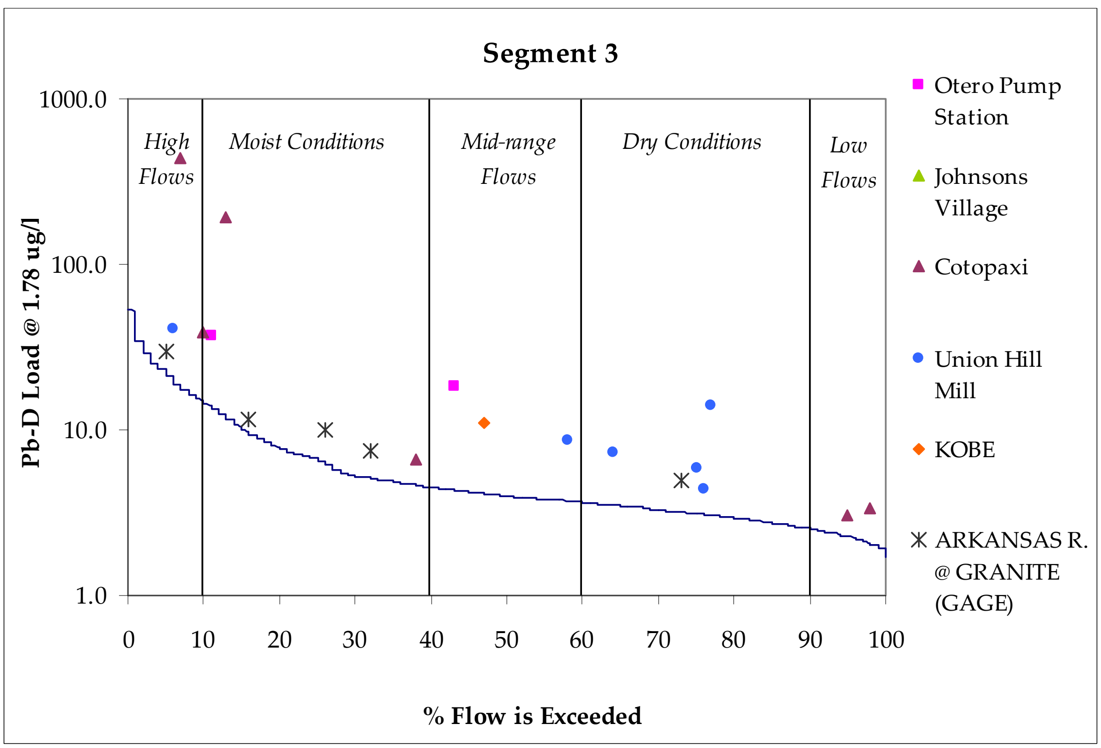
Lead - Segment 3 - 95th% and Median Flows												
							WLA, lbs/day					
Month	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Exisitng Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL	Buena Vista Sanitation District	Salida WWTF	Heart of the Rockies Regional Med. Center	Jesse Lee Pit	Med. Center Replacement Hosp.	Mt. Shavano Fish Hatchery
Jan	4.7	0.244	4.5	0.0	-4.7	0%	0.067	0.089	0.009	N/A	0.001	0.078
Feb	4.3	0.244	4.0	0.0	-4.3	0%	0.067	0.089	0.009	N/A	0.001	0.078
Mar	3.9	0.244	3.7	4.8	0.8	18%	0.067	0.089	0.009	N/A	0.001	0.078
Apr	3.4	0.244	3.2	4.9	1.5	31%	0.067	0.089	0.009	N/A	0.001	0.078
May	5.2	0.244	4.9	18.6	13.4	72%	0.067	0.089	0.009	N/A	0.001	0.078
Jun	9.9	0.244	9.7	0.0	-9.9	0%	0.067	0.089	0.009	N/A	0.001	0.078
Jul	6.0	0.244	5.8	0.0	-6.0	0%	0.067	0.089	0.009	N/A	0.001	0.078
Aug	6.8	0.244	6.5	18.7	12.0	64%	0.067	0.089	0.009	N/A	0.001	0.078
Sep	4.7	0.244	4.4	7.5	2.9	38%	0.067	0.089	0.009	N/A	0.001	0.078
Oct	4.7	0.244	4.4	4.5	-0.2	0%	0.067	0.089	0.009	N/A	0.001	0.078
Nov	4.8	0.244	4.6	0.0	-4.8	0%	0.067	0.089	0.009	N/A	0.001	0.078
Dec	5.4	0.244	5.1	0.0	-5.4	0%	0.067	0.089	0.009	N/A	0.001	0.078

Table 24. Lead total maximum daily load, waste load allocation, and load allocations for Segment 3 (mainstem Arkansas River from Lake Creek to Badger Creek). Stream loads are given for dissolved lead, waste loads are given for potentially dissolved lead. Current stream loads are based on median flows for the Arkansas below Wellsville and 95th percentile monthly dissolved lead concentrations. TMDL allowable loads are calculated using chronic dissolved lead standards and median flows.

Zinc - Segment 3 - 95th% and Median Flows													
							WLA, lbs/day						
Month	TMDL, lbs/day	Total WLA, lbs/day	Total LA, lbs/day	Exisitng Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction to meet TMDL	Buena Vista Sanitation District	Salida WWTF	Heart of the Rockies Regional Med. Center	Jesse Lee Pit	Med. Center Replacement Hosp.	Mt. Shavano Fish Hatchery
Jan	238	7.55	231	241	3	1%	1.984	1.251	0.429	N/A	0.071	3.813
Feb	219	7.55	211	216	-3	0%	1.984	1.251	0.429	N/A	0.071	3.813
Mar	198	7.55	191	193	-5	0%	1.984	1.251	0.429	N/A	0.071	3.813
Apr	176	7.55	169	225	48	22%	1.984	1.251	0.429	N/A	0.071	3.813
May	295	7.55	287	839	544	65%	1.984	1.251	0.429	N/A	0.071	3.813
Jun	589	7.55	581	908	319	35%	1.984	1.251	0.429	N/A	0.071	3.813
Jul	344	7.55	337	403	59	15%	1.984	1.251	0.429	N/A	0.071	3.813
Aug	356	7.55	349	307	-49	0%	1.984	1.251	0.429	N/A	0.071	3.813
Sep	232	7.55	225	196	-36	0%	1.984	1.251	0.429	N/A	0.071	3.813
Oct	233	7.55	225	161	-72	0%	1.984	1.251	0.429	N/A	0.071	3.813
Nov	245	7.55	237	218	-26	0%	1.984	1.251	0.429	N/A	0.071	3.813
Dec	265	7.55	258	152	-113	0%	1.984	1.251	0.429	N/A	0.071	3.813

Table 25. Zinc total maximum daily load, waste load allocation, and load allocations for Segment 3 (mainstem Arkansas River from Lake Creek to Badger Creek). Stream loads are given for dissolved zinc, waste loads are given for potentially dissolved zinc. Current stream loads are based on median flows for the Arkansas below Wellsville and 95th percentile monthly dissolved zinc concentrations. TMDL allowable loads are calculated using chronic dissolved zinc standards and median flows.


Segment 3
100.0
10.0
1.0
0.1
Cd-D Load @ 0.33 ug/l
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
% Flow is Exceeded
Otero Pump Station
Johnsons Village
Cotopaxi
Union Hill Mill
KOBE
ARKANSAS R. @ GRANITE (GAGE)


Segment 3
1000.0
100.0
10.0
1.0
Pb-D Load @ 1.78 ug/l
High Flows
Moist Conditions
Mid-range Flows
Dry Conditions
Low Flows
0
10
20
30
40
50
60
70
80
90
100
% Flow is Exceeded
Otero Pump Station
Johnsons Village
Cotopaxi
Union Hill Mill
KOBE
ARKANSAS R. @ GRANITE (GAGE)

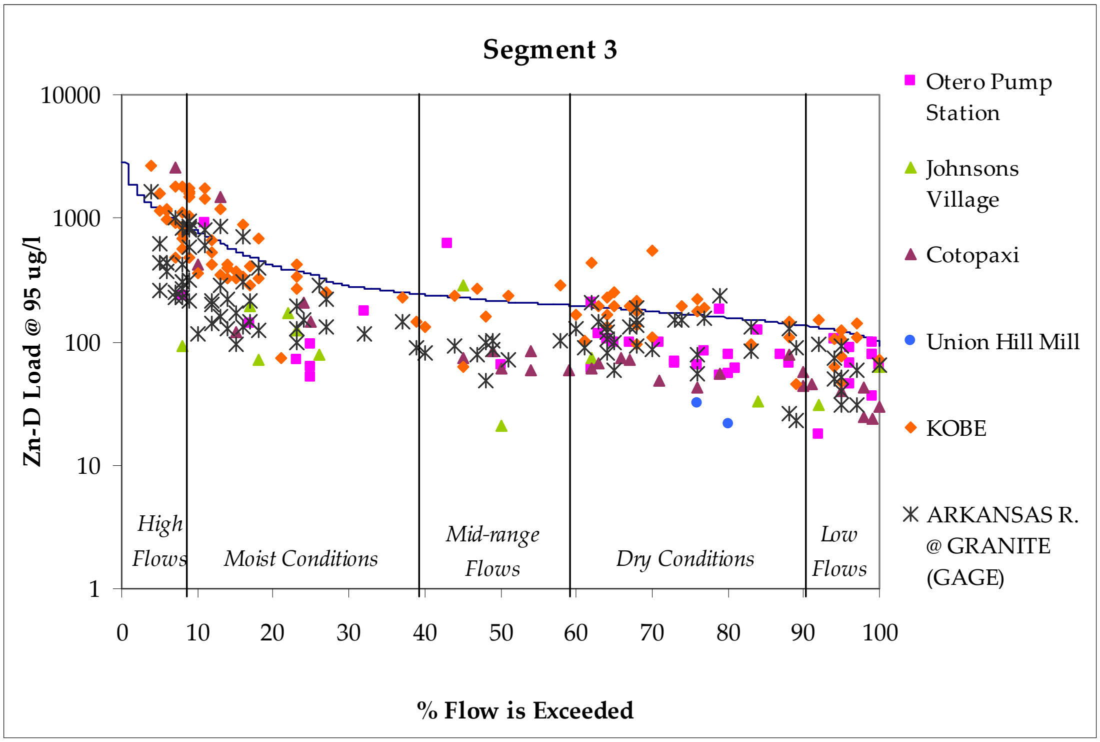
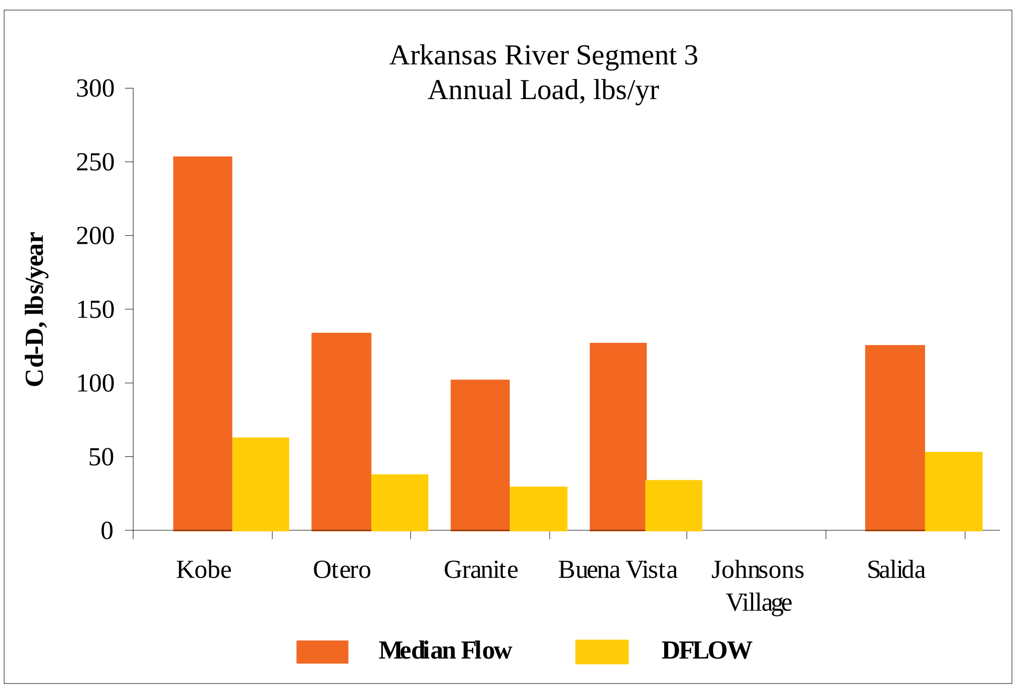
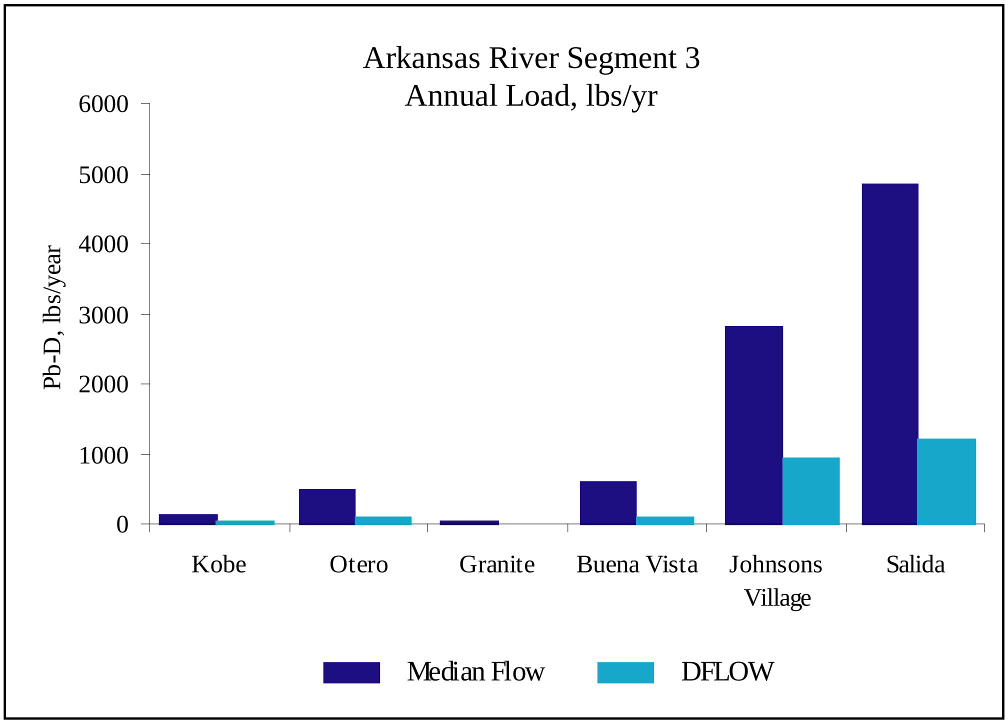


Figure 24. Flow duration curves for dissolved cadmium, lead and zinc loads for Upper Arkansas Segment 3. The load duration curve approximates the cadmium load of an annual Cd-D standard of 0.33 µg/L, Pb-D of 1.78 µg/l and Zn-D standard of 95 µg/l.





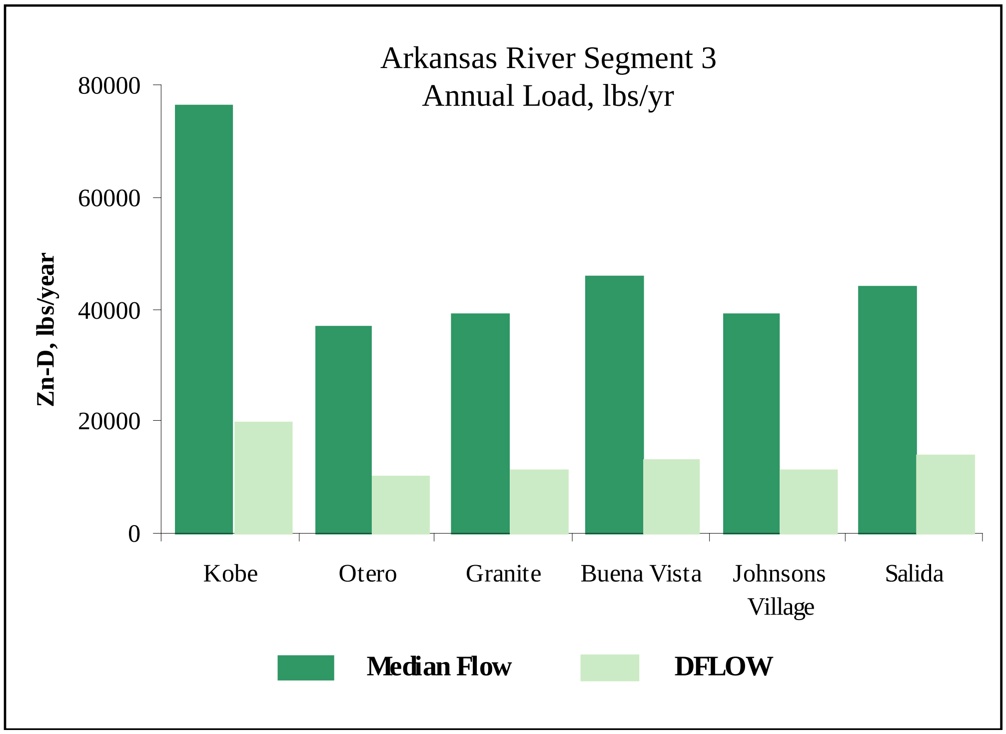


Figure 25. Loading allocations for cadmium, lead and zinc at sampling sites along the mainstem Arkansas River, Segment 3.

Exceedances of the chronic cadmium and lead standards occurred at all of the sampled flow regimes (Figure 26). More data collection during periods of extremely high and low flows would be essential to better understand the effect of flow on instream metals concentrations. If chronic load reductions are completed, Halfmoon Creek would also be in attainment of the acute cadmium trout and acute lead standards.

Because of the limited data set for Segment 5, Halfmoon Creek, a more complete data set would be required in order to provide a more robust TMDL analysis for this segment. Since there are no permitted discharges to this segment, the uncertainty in the TMDL predictions will not affect any permitted point source discharges.

	Cd-D TMDL, lbs/day	Abandoned Mines WLA, lbs/day	LA, lbs/day	Existing Cd-D Stream Load, lbs/day	% Reduction
Halfmoon Creek below North Fork Halfmoon Creek (7183A)	0.009	0.007	0.002	0.035	74%
Halfmoon Creek near Leadville (7183)	0.009	0.008	0.002	0.225	96%
	Pb-D TMDL, lbs/day	Abandoned Mines WLA, lbs/day	LA, lbs/day	Existing Pb-D Stream Load, lbs/day	% Reduction
Halfmoon Creek below North Fork Halfmoon Creek (7183A)	0.037	0.035	0.002	0.397	91%
Halfmoon Creek near Leadville (7183)	0.039	0.037	0.002	0.735	95%

Table 26. Cadmium and lead total maximum daily loads and load allocations for Segment 5 (Halfmoon Creek). Current stream loads are based on median flows for Halfmoon Creek near Malta and 95th percentile annual dissolved cadmium and lead concentrations. TMDL allowable loads are calculated using chronic dissolved cadmium and lead standards and median flows

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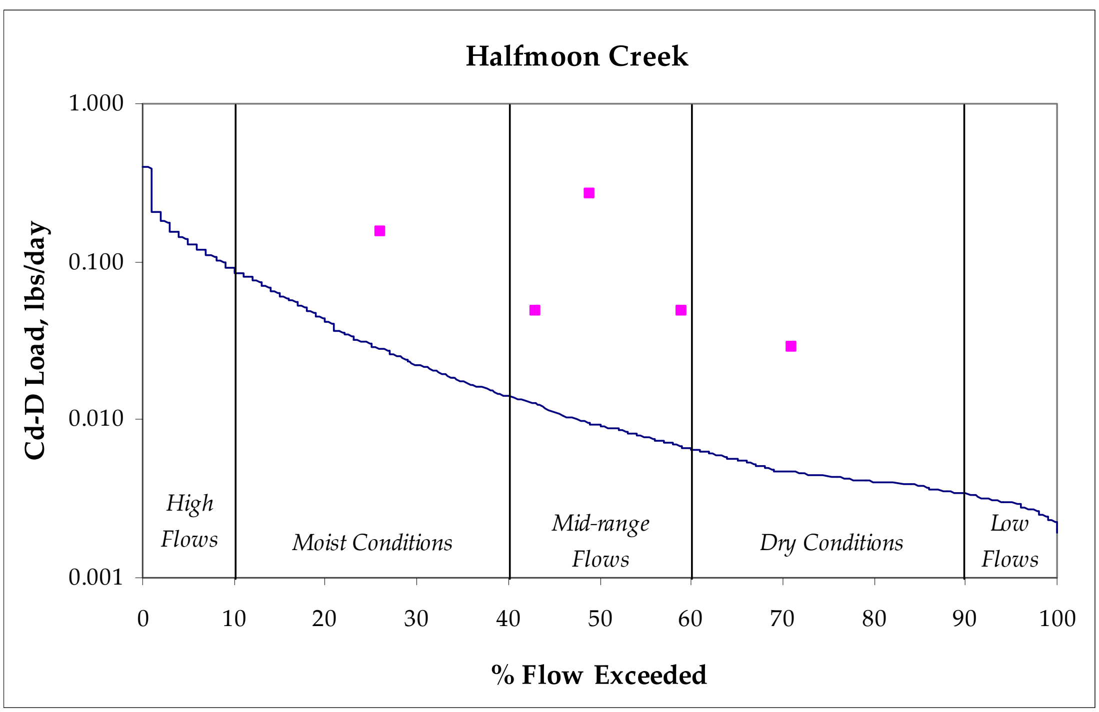

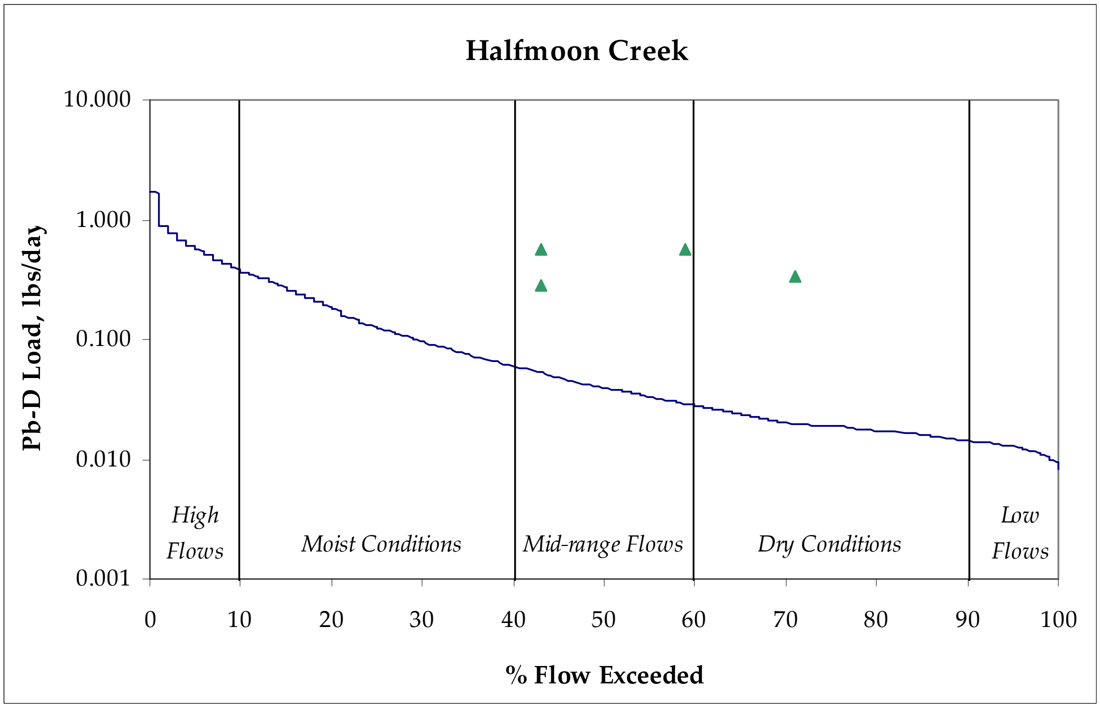

Figure 27. Flow duration curves for dissolved cadmium and lead for Upper Arkansas Segment 5, Halfmoon Creek. The load duration curve approximates the cadmium load of an annual Cd-D standard of 0.18 µg/L. The load duration curve approximates the lead load of an annual Pb-D standard of 0.77 µg/l.

Segment 7

In Segment 7, Evans Gulch, the highest zinc loading occurs during spring runoff in May and June. Consequently, when the critical condition is assessed, the highest load reductions correspond to the start of spring runoff in May, with a 21% reduction, and June, with a 20% reduction required in order to attain chronic zinc standards (Table 27). Only two additional months of the year following spring runoff, require zinc load reductions, July (8%) and August (4%) (Table 27). The allowable TMDL was calculated using median flow values. Flows for Evans Gulch were extrapolated from St. Kevin's Gulch flows using a ratio of drainage areas (St. Kevin's Gulch flows * 1.89). Based on analyses from similar watersheds with abandoned mine influence, the percent load that is attributed to historic mine activity is assumed to be 90%. The remaining load (10%) is allocated to non-point sources and natural background. If chronic load reductions are achieved, Segment 7 will also be in attainment of its acute zinc standard.

Since there was very little hardness data for Evans Gulch, Segment 7, zinc concentrations were plotted based on sample sites (Figure 27). The highest zinc concentrations were observed at the site, Evans Gulch at Highways 91 and 24. More recent zinc concentrations and measured flow data would improve the quality of the assessment, where paired hardness and concentration values could be assessed.

Because of the limited data set for Segment 7, Evans Gulch, a more complete data set would be required in order to provide a more robust TMDL analysis for this segment. Since there are no permitted discharges to this segment, the uncertainty in the TMDL predictions will not affect any permitted point source discharges.

Zinc - Segment 7 - 95th% and Median Flows

Month	TMDL, lbs/day	Abandoned Mines WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction
Jan	1.14	1.0	0.11	0.25	-0.89	0%
Feb	1.52	1.4	0.15	0.25	-1.28	0%
Mar	1.96	1.8	0.20	0.23	-1.73	0%
Apr	2.08	1.9	0.21	0.26	-1.82	0%
May	7.21	6.5	0.72	9.09	1.88	21%
Jun	6.23	5.6	0.62	7.80	1.57	20%
Jul	1.23	1.1	0.12	1.35	0.11	8%
Aug	0.56	0.5	0.06	0.59	0.03	4%
Sep	0.49	0.4	0.05	0.06	-0.42	0%
Oct	0.48	0.4	0.05	0.06	-0.42	0%
Nov	0.71	0.6	0.07	0.09	-0.61	0%
Dec	0.93	0.8	0.09	0.11	-0.82	0%

Table 27. Zinc total maximum daily load and load allocation for Segment 7 (Evans Gulch). The TMDL and current stream loads are based on median flows for Evans Gulch and 95th percentile annual dissolved zinc concentrations. Flows for Evans Gulch were calculated from a ratio of drainage areas from St. Kevin's Gulch (USGS #7080980 * 1.89).

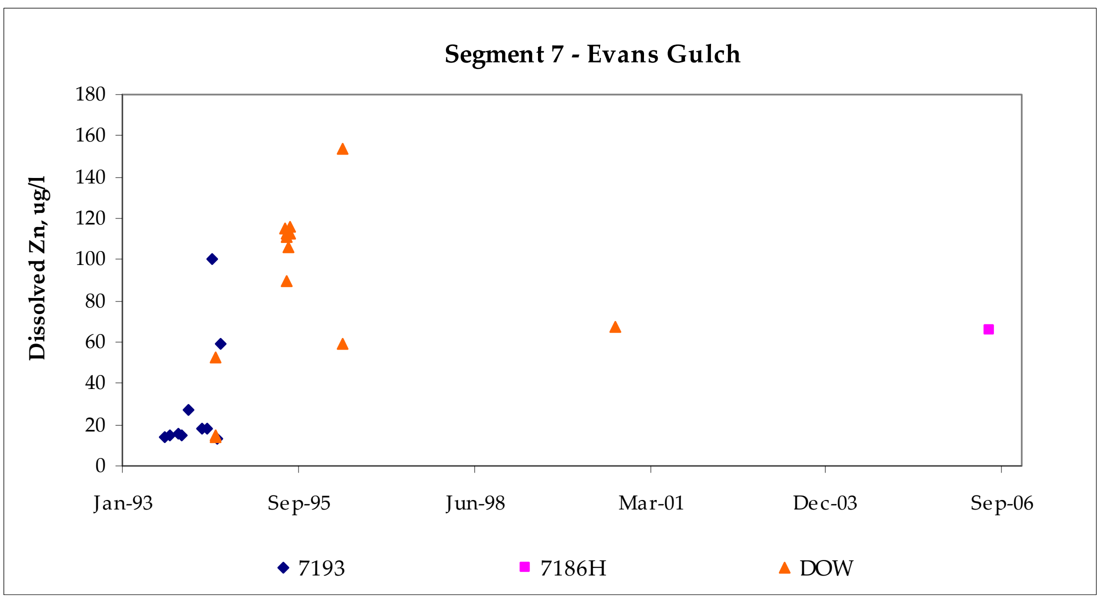

Figure 27. Dissolved zinc concentrations at three sampling sites on the Upper Arkansas Segment 7, Evans Gulch. Zinc concentrations were highest at the CDOW River Watch site, Evans Gulch at Highway 91 and 24.

Segment 11

The Colorado Geological Survey (CGS now DRMS) conducted a NASA-funded survey of the Lake Creek watershed (Segment 11) in Spring of 2002 through Fall 2003. The survey used remote sensing to map the mineralogy related to water quality within the hydrothermally altered watershed and to identify the relative contributions of natural and anthropogenic sources of metals contamination (Bird and Sares et al., 2003). Historic mining in the area was limited to only a few small claims, which were known for relatively low producing but high-grade gold deposits, none of which are known to discharge to the watershed. Production generally came from small, Laramide gold veins in Precambrian igneous rocks (Moran and Wentz, 1974). The watershed is an area of widespread hydrothermal alteration that includes pyrite, various clay minerals, iron oxides, and other minerals associated with acid-sulfate alteration. Springs discharging from this zone typically have pH below 3 and contain high concentrations of metals, including aluminum and iron exceeding 200 mg/L, copper up to 10 mg/L, and sulfate up to 29,000 mg/L (Bird and Sares et al., 2003). Hence, the area provides a unique opportunity to study the impacts from acid rock drainage (ARD) derived from primarily natural sources with only minimal anthropogenic disturbance (Bird and Sares et al., 2003). Previous survey work has identified the South Fork as the primary source of acid and metal loadings in the Lake Creek basin. Significant dilution from the North Fork greatly reduces downstream metals concentrations.

Since Segment 11 does not have chronic standards for all metal parameters, the TMDLs for aluminum and copper are based on the most critical acute conditions and ninety-fifth percentile metals concentrations. TMDLs for cadmium and zinc are based on chronic reductions. Ambient stream concentrations were also calculated using ninety-fifth percentile values in order to provide an implicit margin of safety. All load reductions are considered to be LAs and originate from a natural hydrothermally altered watershed.

In Segment 11, South Fork Lake Creek, the dissolved aluminum TMDL was calculated using an annual median value of 8.2 cubic feet per second. The current stream load is based on the most critical condition, providing an implicit margin of safety. The ninety-fifth percentile aluminum concentration was multiplied by the annual median flow (8.2 cfs) in order to ascertain current stream conditions resulting in a load reduction of 98% (Table 28). The aluminum load must be reduced by 1,587 pounds per day in order to attain the acute aluminum standard of 750 micrograms per liter.

Segment 11 contains only an acute copper standard as well. Similar to aluminum, the dissolved copper TMDL was calculated using an annual median flow value of 8.2 cubic feet per second. The current TMDL is based on the most critical condition, pairing the lowest observed hardness value to calculate the allowable load with the ninety-fifth percentile copper concentration to estimate the instream copper load. The current copper load (81.5 lbs/day) must be reduced by 100% in order to attain the TMDL of 0.100 pounds per day (Table 28).

The dissolved cadmium TMDL was calculated using an annual median flow value of 8.2 cubic feet per second. The current stream load was calculated from a 95^{th}% cadmium concentration and an annual median flow. An 87% reduction is required in order to attain chronic cadmium standards in Segment 11 (Table 28). The South Fork Lake Creek must reduce its cadmium load by 0.072 pounds per day in order to meet the TMDL of 0.011 pounds per day. The entire load reduction is attributed to the natural geology in the watershed and is treated as a load allocation.

Similar to cadmium, the dissolved zinc TMDL was calculated using an annual median flow value of 8.2 cubic feet per second. The current stream load was calculated from a 95^{th}% zinc concentration and an annual median flow. An 81% reduction is required in zinc loading in order to attain the TMDL of 2.67 pounds per day of zinc. Current zinc loads in Segment 11 are approximately 13.8 pounds per day. All of the reduction is assumed to come from non-point source and natural background and is treated as a load allocation.

The metal ions in mine drainage can undergo hydrolysis reactions that release hydrogen ions if the solution is neutralized or oxidized. These metals ions represent a significant source of "latent" or "stored" acidity that has the potential to release additional H+ ions, re-lowering the pH. Values for pH in Evans Gulch, Segment 11, are not in attainment of their acute and chronic standards. By addressing the sources of potential acid mine drainage (Al, Cd, Cu, and Zn contamination), contributions to the low pH values will also be ameliorated. This assumption can be verified upon implementation of abandoned mine remediation plans

If chronic load reductions for cadmium and zinc are achieved in South Fork Lake Creek, Segment 11 would also be in attainment of its acute standards. Load duration curves were not derived for Segment 11 since the period of record for flow was from 1987-1998 and sampling activity primarily occurred between 2000 and 2006. One hundred percent of the load reductions are considered to be from a natural hydrothermally altered watershed and are thus given load allocations.

Sampling Site	Al-D TMDL, lbs/day	Total Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction
S. Fork Lake Creek	33.2	0.0	33.2	1620.6	1587.4	98%
Sampling Site	Cd-D TMDL, lbs/day	Total Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction
S. Fork Lake Creek	0.011	0.000	0.0	0.083	0.072	87%
Sampling Site	Cu-D TMDL, lbs/day	Total Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction
S. Fork Lake Creek	0.100	0.000	0.1	81.5	81.4	100%
Sampling Site	Zn-D TMDL, lbs/day	Total Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction
S. Fork Lake Creek	2.67	0.00	2.7	13.8	11.1	81%

Table 28. Aluminum, cadmium, copper and zinc total maximum daily loads, waste load allocations, and load allocations for Segment 11 (South Fork Lake Creek). Stream loads are given for dissolved metals.

Because natural ambient water quality levels are consistently higher than specific numeric levels outlined in Regulation 31, The Basic Standards and Methodologies for Surface Water, it may be appropriate to adopt site-specific standards for Segment 11 of the Upper Arkansas River basin at the next triennial review.

Segment 12a

In Segment 12a, a tributary to the mainstem Arkansas River (mainstem Chalk Creek), the average daily lead and zinc loads do not currently meet the assigned chronic standards (Tables 29 and 30). The lead load is highest in May and June, corresponding to the highest (and only) monthly load reductions (Table 29). Load reductions of 51% and 72% are required in May and June, respectively. The high load reductions required in June are due to an unusually high lead concentration of six micrograms per liter at the site Chalk Creek downstream of Grouse Gulch and Baldwin Creek in June of 2006. Based on lead concentrations directly below historic mine influence and at the mouth just above the confluence with the Arkansas River, sixty-three percent of the lead load is attributable to the influence of these abandoned mine features.

Currently, Colorado Division of Wildlife (CDOW) operates the Chalk Cliffs Rearing Unit in Segment 12a, which is a cold water facility that annually raises 700,000 10-inch rainbow trout. The Water Quality Control Division (WQCD) performed an antidegradation review for the fish hatchery general permit, and determined for the discharges qualifying for a general permit, that the activity will not result in significant degradation of reviewable waters with respect to adopted narrative or numeric standards as long as all of the general permit limitations are met. Because it has been determined that this facility does not require effluent limitations for metals constituents, it will not be given a waste load allocation in the TMDL document.

The chronic zinc load is highest during spring runoff (May and June), however, the greatest load reductions occur in the months of September through December, with reductions of over 89% - 91% required. Load reductions remain between 46% in July to 85% in August. Based on zinc concentrations directly below historic mine influence and at the mouth just above the confluence with the Arkansas River, eighty-four percent of the zinc load is attributable to the influence of these abandoned mine features.

If chronic zinc load reductions are achieved in Segment 12a, the segment will still be in attainment of the acute zinc standard. Acute zinc exceedances are allowed once in a three year period. When the chronic reductions are applied to ambient zinc concentrations, two exceedances of the acute zinc standard still occur, both in 2000 and 2005. According to Regulation 31, the segment still, however, remains in attainment of the acute standard.

Figures 28 and 29 illustrate the average annual contribution from the different sources: point source dischargers, abandoned mine activity, and non-point sources, or natural background. The waste load allocation for permitted dischargers remains constant throughout the year; however their contribution to the annual load varies by month. On an annual basis, non-permitted point sources (abandoned mines, 83%) and permitted dischargers (1%), and non-point sources, or natural background sources, account for approximately 16% of the average annual lead load (Figure 29). Non-permitted point sources, as from historic mining activity, contribute the largest portion of the average annual zinc load to Chalk Creek (63%) (Figure 29). Non-point sources account for approximately 37% of the load while the permitted dischargers account for about 1% (Figure 29).

Lead - Segment 12a - 95th% and Median Flows										
								WLA, lbs/day		
Month	TMDL, lbs/day	Point Source WLA, lbs/day	Abandoned Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction	Mt. Princeton Hot Springs Resort	Silver Cliff Ranch	Young Life Campaign, Inc.
Jan	0.11	0.001	0.07	0.04	0.0	-0.1	0%	0.0004	0.0004	0.0004
Feb	0.11	0.001	0.07	0.04	0.0	-0.1	0%	0.0004	0.0004	0.0004
Mar	0.09	0.001	0.05	0.03	0.0	-0.1	0%	0.0004	0.0004	0.0004
Apr	0.07	0.001	0.04	0.02	0.0	-0.1	0%	0.0004	0.0004	0.0004
May	0.22	0.001	0.14	0.08	0.4	0.2	51%	0.0004	0.0004	0.0004
Jun	0.61	0.001	0.38	0.23	2.1	1.5	72%	0.0004	0.0004	0.0004
Jul	0.48	0.001	0.30	0.18	0.4	0.0	0%	0.0004	0.0004	0.0004
Aug	0.27	0.001	0.17	0.10	0.0	-0.3	0%	0.0004	0.0004	0.0004
Sep	0.20	0.001	0.13	0.08	0.0	-0.2	0%	0.0004	0.0004	0.0004
Oct	0.17	0.001	0.11	0.06	0.0	-0.2	0%	0.0004	0.0004	0.0004
Nov	0.15	0.001	0.09	0.05	0.0	-0.1	0%	0.0004	0.0004	0.0004
Dec	0.12	0.001	0.08	0.04	0.0	-0.1	0%	0.0004	0.0004	0.0004

Table 29. Lead total maximum daily load, waste load allocations, and load allocations for Segment 12a (Chalk Creek). Stream loads are given for dissolved lead, waste loads are given for potentially dissolved lead. Since there were no exceedances of the acute lead standard, the allowable load and existing stream load were based on median monthly flows for Chalk Creek near Nathrop.

Zinc - Segment 12a - 95th% and Median Flows										
								WLA, lbs/day		
Month	TMDL, lbs/day	Point Source WLA, lbs/day	Abandoned Mine WLA, lbs/day	Total LA, lbs/day	Existing Stream Load, lbs/day	Reduction to meet TMDL, lbs/day	% Reduction	Mt. Princeton Hot Springs Resort	Silver Cliff Ranch	Young Life Campaign, Inc.
Jan	6.70	0.192	5.47	1.04	35.3	28.6	81%	0.064	0.064	0.064
Feb	6.70	0.192	5.47	1.04	30.7	24.0	78%	0.064	0.064	0.064
Mar	5.41	0.192	4.39	0.84	28.3	22.8	81%	0.064	0.064	0.064
Apr	4.45	0.192	3.58	0.68	27.5	23.0	84%	0.064	0.064	0.064
May	15.92	0.192	13.21	2.52	52.9	37.0	70%	0.064	0.064	0.064
Jun	42.15	0.192	35.24	6.71	194.6	152.4	78%	0.064	0.064	0.064
Jul	28.21	0.192	23.53	4.48	51.8	23.6	46%	0.064	0.064	0.064
Aug	15.80	0.192	13.11	2.50	103.6	87.8	85%	0.064	0.064	0.064
Sep	12.06	0.192	9.97	1.90	134.0	121.9	91%	0.064	0.064	0.064
Oct	10.23	0.192	8.43	1.61	106.8	96.6	90%	0.064	0.064	0.064
Nov	8.62	0.192	7.08	1.35	85.6	77.0	90%	0.064	0.064	0.064
Dec	7.18	0.192	5.87	1.12	66.4	59.2	89%	0.064	0.064	0.064

Table 30. Zinc total maximum daily load, waste load allocations, and load allocations for Segment 12a (Chalk Creek). Stream loads are given for dissolved zinc, waste loads are given for potentially dissolved zinc. TMDL allowable loads and existing stream loads were based on median flow values for Chalk Creek near Nathrop, were calculated using monthly median flows.

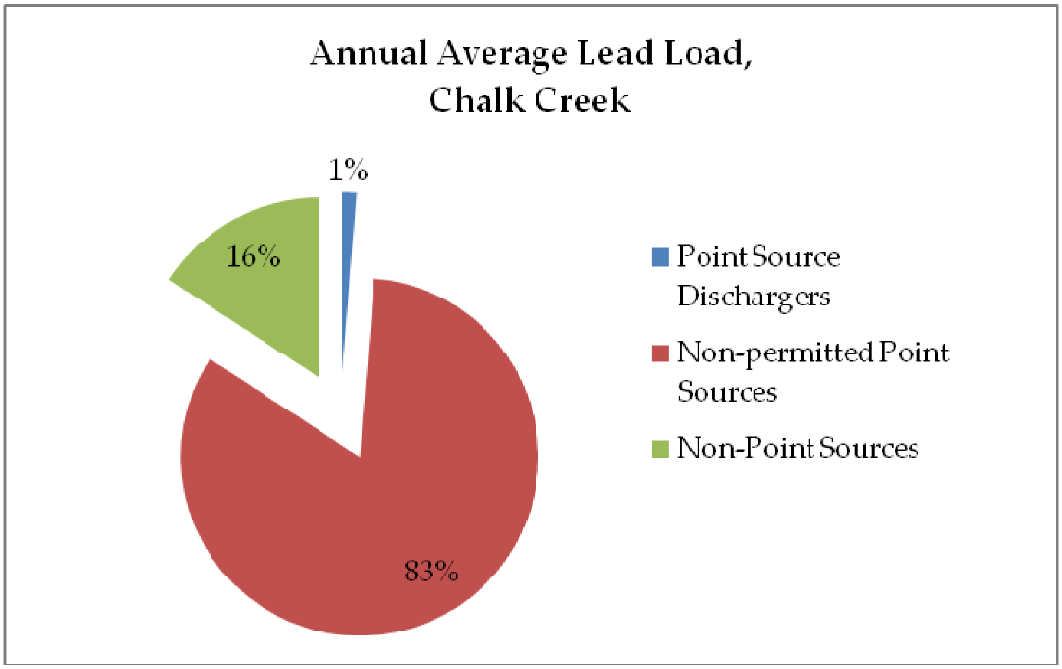

Figure 28. Pie graph for Segment 12a, Chalk Creek, which demonstrates annual average TMDL allocations for dissolved lead.

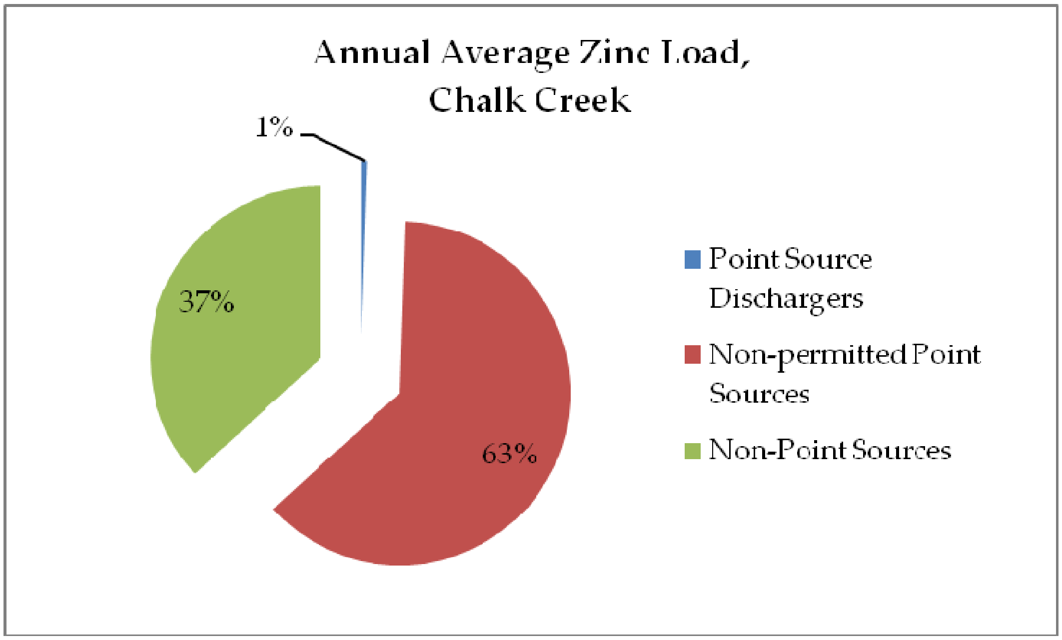

Figure 29. Pie graph for Segment 12a, Chalk Creek, which demonstrates annual average TMDL allocations for dissolved zinc.

Margin of Safety

An explicit margin of safety was not included in this assessment. There is an overall implicit margin of safety with regards to this assessment due to the calculation of ambient stream concentrations with ninety-fifth percentile values. As a result, proposed reductions also address exceedances of the acute cadmium (trout) standard as well as all other acute standards assigned to these listed segments. The proposed reductions are conservative over-estimates of the reductions needed in order to attain chronic standards; however, they also take into account the stringent acute trout standards for cadmium. Monthly TMDLs reflect the extremely variable hydrograph of the Arkansas River Basin, and adequately reflect the current water quality situation. In conjunction with continued Superfund participation upstream, the actual loading levels would likely be reduced even further through time as cleanup activities continue and are completed.

VII. RESTORATION PLANNING AND IMPLEMENTATION PROCESS

The percentage of loading reductions necessary to meet site-specific standards for cadmium and zinc in segments 2b and 2c are listed in tables 19 through 22. The major sources contributing to the elevated level of metals in these Arkansas River segments are abandoned mine workings and flow from California Gulch. Loading reductions for Segment 3 of the Arkansas River are shown in tables 23 through 25. Figure 25 identifies the cadmium, lead and zinc loads throughout the length of the entire segment. TMDL load reductions for Segment 5 are demonstrated in Table 26, TMDL load reductions for Segment 7 are demonstrated in Table 27, while Table 28 identifies the TMDL for Segment 11. Lastly, the TMDL for Segment 12a, Chalk Creek, is demonstrated in tables 29 and 30. Zinc loads in Chalk Creek demonstrate an increase below the Mary Murphy Mine.

With the lack of flow data available for individual mine workings, and the diffuse nature of non-point source loading, it is difficult to appropriate loading reductions to each particular source. Consequently, estimates of loading reductions are a composite of the non-permitted point sources and non-point sources for each segment.

The Environmental Protection Agency started drilling a new well into the Leadville Mine Drainage Tunnel (LMDT) in May of 2008, which will allow the EPA to install a pump to pull trapped water from inside the LMDT. The US Bureau of Reclamation (USBR) has agreed to treat the contaminated water coming from the mountain before it flows into the Arkansas River. On February 27, 2008, the EPA started pumping trapped water from the Leadville Mountain at the Gaw shaft. Water pumped from the Gaw shaft is not contaminated and flows into California Gulch.

Previous Water Quality Improvements in the Watershed

In 1983, California Gulch (COARUA06) was placed on the National Priorities List (NPL) for clean-up under Superfund because of concerns about the impact of heavy metals on the Arkansas River, especially Segments 2b and 2c. Reduction of metals in Arkansas River basin Segments 2b and 2c will be accomplished mainly through Superfund/CERCLA activities and treatment of abandoned mine drainage in the basin. Remediation in California Gulch began in 1988 to minimize the flow of acidic water from the Yak Tunnel. Cleanup consisted of a surge pond, water treatment plant and a groundwater monitoring network. The water treatment plant began operation in the spring of 1992. Settlement of Natural Resource Damages (NRDs) began pursuant to a Memorandum of Understanding (MOU) process that was agreed to by all of the involved parties in the spring of 1999. Water quality in these listed segments will be affected by the ongoing Superfund remediation efforts of California Gulch.

Remediation work on Segment 12a, Chalk Creek, has been ongoing since 1990. Tailings piles from the Mary Murphy and Iron Chest mines were consolidated and revegetated in the summer of 1991. During this time, remediation of the Golf Tunnel also occurred through the diversion of the adit water through a settling pond and reconstructed and natural wetlands.

Projects are currently underway at the Mary Murphy Mine to determine through dye-tracer studies if water from snow and rain that enters the mine eventually finds its way to discharge into Chalk Creek. If the mine surface depressions can be identified as sources of water inflow, a subsequent project to fill, seal, and cap the stopes may be undertaken to prevent infiltration of water into the underground workings.

The Division of Mine Reclamation and Safety (formerly Colorado Department of Minerals and Geology) conducted a demonstration project of an underground diversion to control metals loading to the Main Adit level of the Mary Murphy Mine. A temporary, underground earthen dam was constructed to segregate the clean groundwater inflows from the mine discharge, reducing the total discharge needing treatment from the 90 to 222 gpm (low flow-high flow) range to the 5 to 20 gpm range (http://www.epa.gov/nps/Sections 319III/CO.htm). Subsequent sampling demonstrated the diversion reduced dissolved zinc concentrations in the Main Adit flow from 5,000 micrograms per liter to 250 micrograms per liter. Therefore, if clean inflows can be separated from mine discharge, and if the volume of the contaminated flows are greatly reduced, it may be technically feasible to eliminate up to 80% of the pollution within a mine without having to treat the discharge in perpetuity (http://www.epa.gov/nps/Sections 319III/CO.htm).

Monitoring

In order to insure that the TMDL is adequately protective of the Arkansas River and tributary segments and to evaluate the progress of heavy metal treatment from the California Gulch Superfund remediation, monitoring is required.

Conclusion

The goal of this TMDL is the attainment of Aquatic Life Use-based standards for segments 2b, 2c, 3, 5, 7, 11, and 12a of the upper Arkansas River basin.

VII. PUBLIC INVOLVEMENT

There has been a strong public participation in protecting and enhancing the water quality of the Arkansas River Basin. Since remediation activities began in the upper Arkansas River basin, collection of basin-wide surface and ground water quality data have served to track the level of improvements in the Upper Arkansas River. Many organizations have been extensively involved including, but not limited to, the Colorado Department of Public Health and Environment Hazardous Materials and Waste Management, and Water Quality Control Divisions, Environmental Protection Agency, Colorado Division of Wildlife, U.S. Fish and Wildlife Service and the potentially responsible parties (PRPs).

These organizations compose the California Gulch Biological Technical Assistance Group (BTAG) that meets to discuss issues associated with the aquatic community of the Upper Arkansas River.

The general public has also had the opportunity to be involved in the Water Quality Control Commission (WQCC) hearings. Throughout the years, the WQCC has adopted new, temporary modifications for this segment where the public has had the opportunity to get involved. Opportunities have also been available through the 303(d) listing process; which has a public notice period for public involvement.

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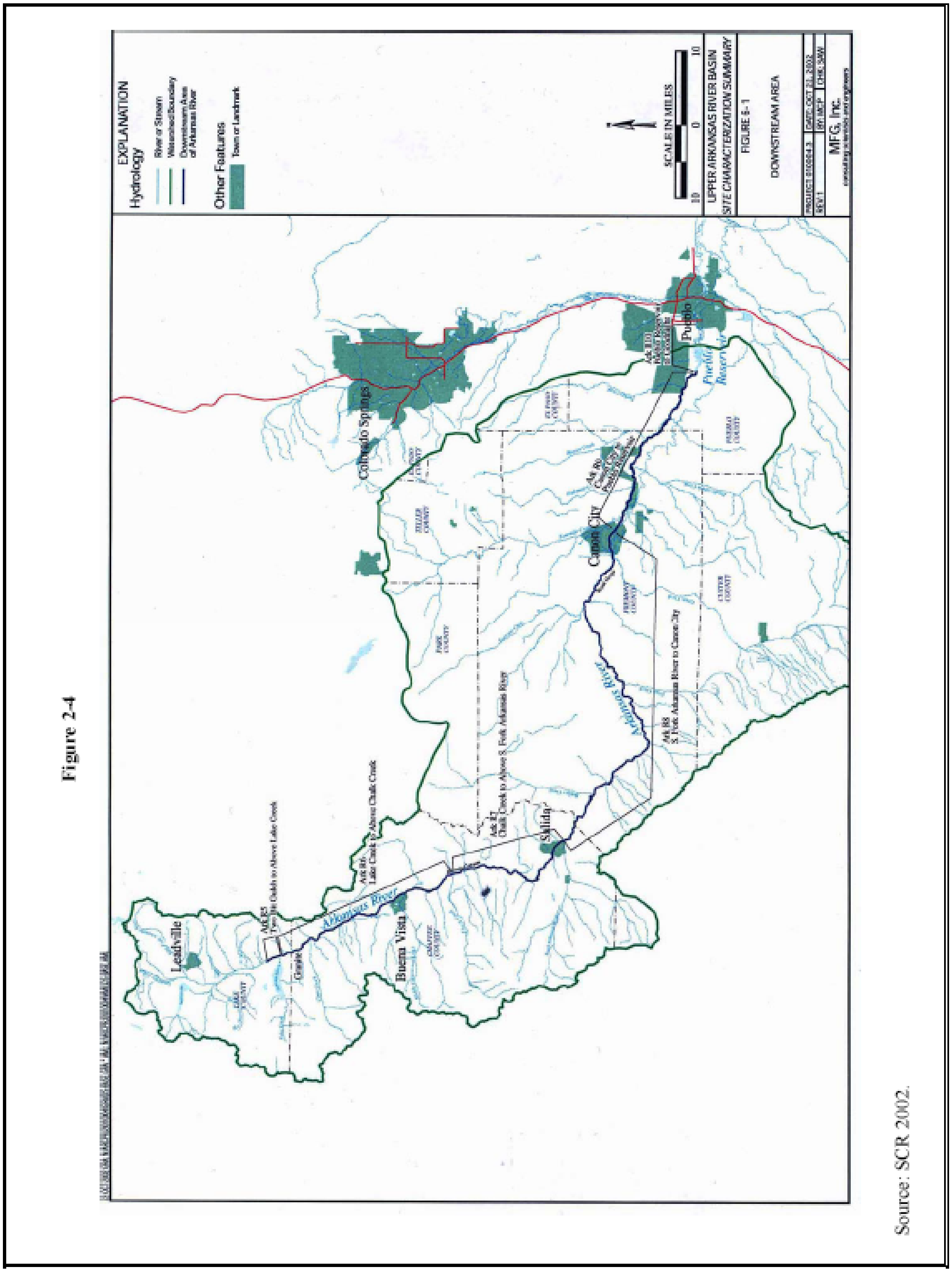

Map of Upper Arkansas River Basin taken from the Site Characterization Report of the Upper Arkansas River Basin in 2002.