Total Maximum Daily Load Assessment
Silver Creek
Dolores County, Colorado

Colorado Department of Public Health and Environment
Water Quality Control Division

May, 2008

TMDL Summary	
Waterbody Description / WBID	Mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River, COSJDO09.
Pollutants Addressed	Dissolved Cadmium and Dissolved Zinc
Relevant Portion of Segment (as applicable)	Mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River.
Use Classifications / Designation	Segment 9: Aquatic Life Cold 2, Recreation E (May 1 to Oct 31), Recreation N (Nov 1 to Apr 30), Agriculture
Water Quality Targets (for dissolved fraction of metals)	Segment 9 — Chronic / Acute Cd-D — TVS / TVS Zn-D — TVS / TVS
TMDL Goal	Attainment of TVS Standard for cadmium and zinc

EXECUTIVE SUMMARY

The Silver Creek watershed is tributary to the Dolores River (Figure 1). The mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River appeared on the Colorado 1998 303(d) list for non-attainment of dissolved zinc standards (Table 1) (WQCC 2006a). Segment 9, below Rico's water supply diversion was also listed for cadmium in 2004. Conversely, in 2006, cadmium was removed from the list. Since the delisting, however, a new, more stringent, cadmium standard was adopted at the San Juan/Dolores basin hearings in 2006, and Silver Creek is once again in exceedance of TVS for cadmium. These metals impair the Aquatic Life Cold 2 classification. The high concentration of metals is primarily the result of mining activity in the watershed between the1880's and the late 1970's. There are currently no active mines on Silver Creek.

Segment #	Segment Description	Portion	303(d) Listed Contaminants
Segment 9	Mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River	Mainstem	Zn

Table 1. Segments within the Silver Creek watershed that appear on the 2006 303(d) list of impaired waters for excessive heavy metals.

Silver Creek contains a number of mine-site related features, however. A significant amount of Colorado Voluntary Cleanup and Redevelopment Act (VCUP) work has been completed with the Argentine tunnel and tailings, located in the Silver Creek watershed. There still remains a significant seep located downgradient of the tailings, which runs parallel and eventually reaches a confluence with Silver Creek. This seep is also a source of metals and a water quality concern.

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 point source discharge, 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) $$TMDL=WLA+LA+MOS$$

Alternatively, 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).

The mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River is included in the 2006 303(d) list for exceeding the Aquatic Life use standards for zinc (Table 1) (WQCC, 2006b). Since the 2006 303(d) listing, a new cadmium standard was adopted. This more stringent standard was adopted at the San Juan and Dolores River Basin hearings in 2006(WQCC, 2006c). Consequently, segment COSJDO09 is also in exceedance of the new cadmium TVS standard. As a result, this TMDL will address both cadmium and zinc.

II. GEOGRAPHICAL EXTENT

The Silver Creek drainage basin lies to the east of the town of Rico and encompasses approximately five square miles. It is flanked on the south by Blackhawk Mountain, the highest peak in the area, with an elevation of 12,677 feet. Many small tributaries flow into Silver Creek, which is 3.5 miles long and the principle drainage in the basin.

Silver Creek flows westward under State Highway 145 through a concrete box culvert, before flowing northwest to its confluence with the Dolores River. The stream discharge peaks in the late spring at around 100 cubic feet/second during peak runoff. The stream channel is about six feet in depth by six to eight feet in width. Bed-load (bottom substrate) is not embedded (loose) and consists of cobbles and boulders from four to eighteen inches in diameter (King, 2006).

The creek is very steep (~ 13% gradient), confined, has high flow energy and is relatively unstable. Man-made alterations have contributed to its instability. Although the active channel occupies a small area, it can contribute large flow volumes, avalanches, and debris flows. The mouth of the creek is a debris fan as a result of those debris flows (King, 2006).

There are source areas within this catchment that are releasing metals into solution.

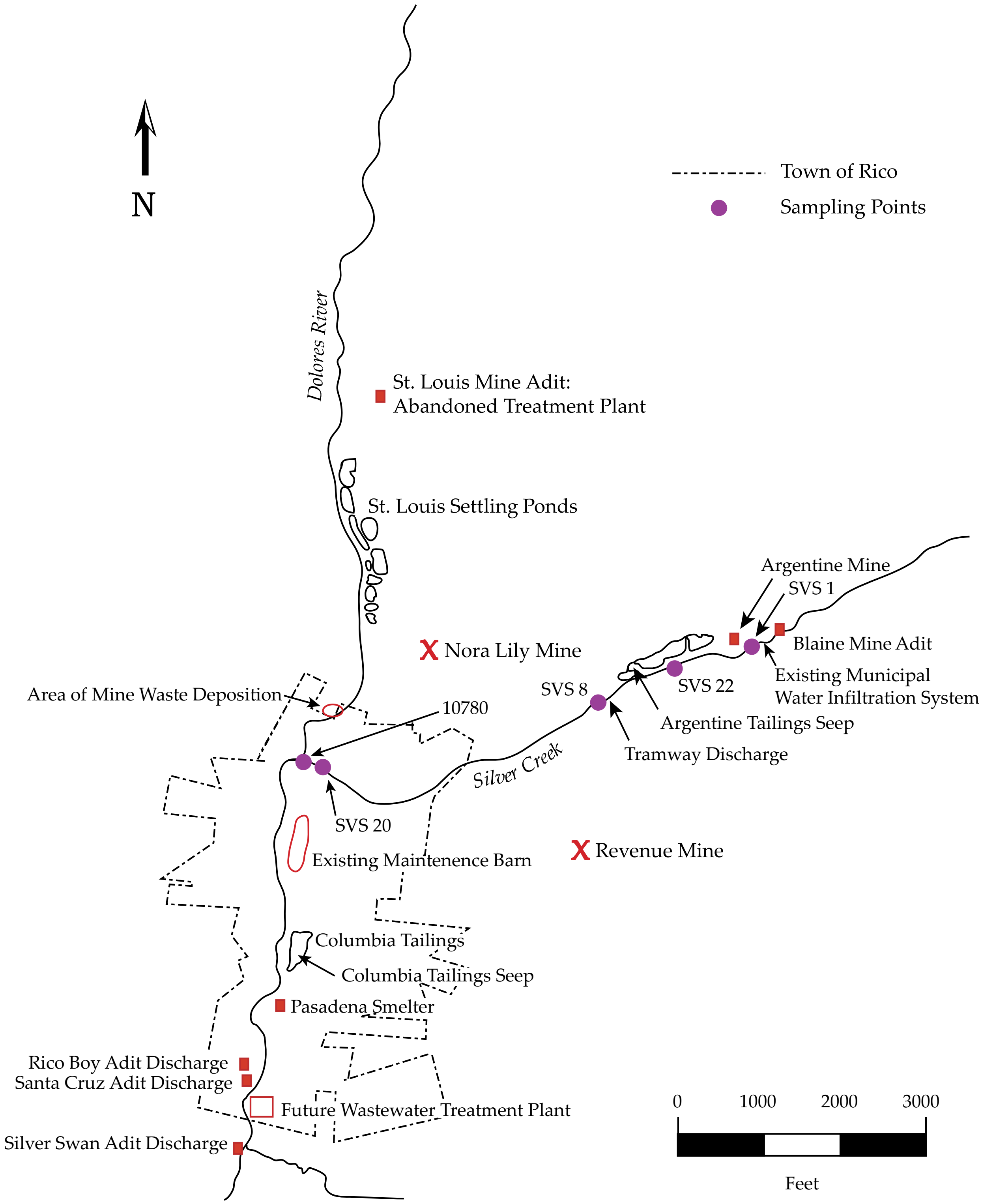

Figure 1. The Silver Creek watershed.

These source areas seem to be routinely associated with the Argentine tailings pile area and an unnamed adit below the Argentine seep associated with the overhead tramway along Silver Creek, but above the Dolores River confluence.

The Nora Lily Mine, which is located below the St. Louis adit to the east of the Dolores River, generates an unknown contribution of degraded water to the Dolores River and the St. Louis settling ponds. The Revenue Mine, which is located on the south side of Silver Creek, contains several mine waste dumps with seeps that may contribute to the degraded water quality of Silver Creek. Since there is no discernable point discharge associated with the mine, it is difficult to isolate its specific contribution to metals concentrations in Silver Creek.

Segment 9 was identified on Colorado's 2006 303 (d) list as not supporting the use classification for aquatic life due to high levels of zinc. In addition, Silver Creek also exceeds the new cadmium standard adopted in 2006.

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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 and zinc. The specific numeric standards assigned to the listed stream segments are contained in the Classifications and Numeric Standards for the San Juan River Basin and Dolores River Basin (WQCC, 2006c) (Table 4). In this instance, cadmium and 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, Water Supply and Agricultural Use Classifications.

Date (Cycle Year) of Current Approved 303(d) list: 2006		
WBID	**Segment Description**	**Designated Uses & Impairment Status**
COSJDO09	Mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River	Aquatic Life Cold 2: Impaired Recreation E: Not Impaired Recreation N: Not Impaired Agriculture: Not Impaired

Table 2. Designated uses and impairment status for Segment 9, mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River.

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). Chronic standards represent the level of pollutants that protect 95 percent of the genera from chronic toxic effects of metals. Chronic standards were therefore used in the Silver Creek TMDL since they represent a more conservative approach than the acute standards. 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).

Most of the relevant standards for the stream segments addressed in this document are Table Value Standards, which vary based on hardness. Because hardness fluctuates seasonally, standards are listed on a monthly basis using the average hardness for each month to calculate the standard. Hardness values were significantly higher downstream of the Argentine Seep as opposed to upstream background values, and therefore more lenient standards were applicable. However, exceedances of the standards at sites downstream of the Argentine Tailings Pile were common. Minimum monthly hardness values were used to generate TMDL loads which provides a conservative element and implicit margin of safety to loading calculations (See Section VI: MOS).

Acute cadmium standards were exceeded on four sampling dates at the sampling site on Silver Creek just upstream of the Argentine Tailings Pile (n=1) and Silver Creek at Highway 145 (n=3). Acute exceedances occur in approximately five percent of the samples, and according to

303(d) Listing Methodology; Silver Creek Segment 9 is in attainment of the acute standard despite the exceedances (not to be exceeded more than once every three years on the average).

Acute zinc standards are frequently exceeded in Segment 9 of Silver Creek. Zinc concentrations exceed the corresponding acute standard in seventy-nine of the eighty-five samples (93%). Chronic zinc standards are more stringent than acute zinc standards, therefore if chronic zinc standards are consistently attained, Silver Creek would also be attaining acute zinc standards.

The stream segment addressed here is use classified as Aquatic Life Cold 2, Recreation E (May 1 to Oct 31), Recreation N (Nov 1 to Apr 30), and Agriculture. The elevated levels of cadmium and zinc exceed the Aquatic Life standards. All other numeric standards are attained and other assigned uses are supported.

Water Quality Criteria for Impaired Designated Uses		
WBID	**Impaired Designated Use**	**Applicable Water Quality Criteria and Status**
COSJDO09	Aquatic Life Cold 2	Dissolved Phase Cd (1) / Not Attained Dissolved Phase Zn (1) / Not Attained
Applicable State or Federal Regulations: (1) Classifications and Numeric Standards for the San Juan River Basin and Dolores River Basin		

Table 3. Ambient water quality criteria and status for Segment 9, mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River.

	Silver Creek Background			Silver Creek downstream of Mine Influence		
	Hardness mg/L	Cd-D,ug/L TVS	Zn-D, ug/L TVS	Hardness mg/L	Cd-D, ug/L TVS	Zn-D, ug/L TVS
Jan	122	0.49	147.3	260	0.87	280.7
Feb	123	0.50	148.3	261	0.87	281.6
Mar	136	0.53	161.6	300	0.97	317.1
Apr	89	0.39	112.6	179	0.66	204.2
May	57	0.28	77.0	105	0.44	129.6
Jun	55	0.27	74.7	73	0.33	95.1
Jul	75*	0.34	97.3	204	0.73	228.3
Aug	95	0.41	119.0	187	0.68	211.9
Sep	96*	0.41	120.1	233	0.80	255.7
Oct	97	0.41	121.1	204	0.73	228.3
Nov	126	0.51	151.4	249	0.84	270.5
Dec	104	0.44	128.5	221	0.77	244.4

Table 4. Average hardness and chronic stream standards for 303(d) listed segment of Silver Creek. Data are from Colorado Department of Public Health and Environment (CDPHE) and Short Elliott Hendrickson, Inc. (SEH).

IV. PROBLEM IDENTIFICATION

There are no permitted dischargers on Silver Creek. Much of the heavy metal loading throughout the Silver Creek basin is the result of natural geologic conditions and historic mining activities. The Silver Creek watershed began experiencing widespread mining activity throughout the basin beginning in the 1880's with silver mining. The mining operations were intermittent until 1926 when the Rico-Argentine Mining Company began rebuilding the mining industry, and mining continued sporadically throughout the region. In 1953, a sulfuric acid plant was constructed and operated until 1965. The mine resumed operation and remained in steady production of lead and zinc until the mid 1970's. The Atlantic Ritchfield Company (ARCO) assumed operation of the mine before it was sold to the Rico Development Corporation (RDC) in 1988. RDC was not actively involved in mining at the time; consequently, they let their discharge permit to the Dolores River lapse (Permit #CO-0029793). RDC stopped treating the mine discharge completely in 1996.

Originally the mine had two outfalls, one to Silver Creek (the Blaine Tunnel) and one to the Dolores River (the St. Louis Tunnel). The Blaine tunnel was eliminated as a discharge point from the permit in 1990 when a concrete barrier was installed to redirect flow from the Blaine Tunnel to the St. Louis Tunnel, which discharges directly into the Dolores River. However, seepage from the vicinity of the Blaine Tunnel to Silver Creek continues to be a problem. Additionally, the Argentine Seep and a presently unnamed seep associated with the overhead tramway seem to be discharging into Silver Creek directly (King, 2006).

In 2001, the Rico-Argentine Mine area took part in a Water Quality Assessment (WQA) in conjunction with the Colorado Water Quality Control Division (WQCD). The dispute over ownership of the St. Louis Tunnel, however, remains unresolved. Under the VCUP program, ARCO has removed and/or stabilized or capped mine tailings that had been located in or adjacent to Silver Creek and the Dolores River, but degraded water quality still remains in Silver Creek downstream of the town of Rico's water supply diversion. There is an innate capacity within the water quality of Silver Creek that provides significant buffering and dilution of metals concentrations, however, it is not enough to meet TVS standards (King, 2006).

The high cadmium and zinc concentrations within the 303(d) listed segment of the Silver Creek basin exceed the standards established to protect aquatic life. Biological studies began in the 1990's by the U.S. Environmental Protection Agency (EPA) and the Colorado Water Quality Control Division (WQCD) concluded that cadmium and zinc threaten trout and macroinvertebrates.

In 1984, a CDOW study demonstrated that "Silver Creek was investigated and found to have little aquatic life because of the heavily mineralized water below the mines; however CDOW stocked native cutthroat approximately two miles above Rico within the Silver Creek drainage and were found to be doing well" (USEPA, 1994). In 2001, in a study by C. Derfus (Derfus, 2001), fish were observed in pool areas in the Dolores River below the confluence of Silver Creek and within Silver Creek itself. Additionally, there was found to be a decrease in the number and type of sensitive invertebrate species in the Dolores River immediately above and below the town of Rico (King, 2006). Colorado Division of Wildlife (CDOW) current records indicate the presence of brook trout in Silver Creek.

V. WATER QUALITY GOALS

The water quality goal for the 303(d) listed segment of Silver Creek is attainment of the Aquatic Life Cold 2 use classification. Originally the Rico-Argentine mine had two outfalls, one to Silver Creek (the Blaine Tunnel) and one to the Dolores River (the St. Louis Tunnel). The Blaine tunnel was eliminated as a discharge point from the permit in 1990 when a concrete barrier was installed to redirect flow from the Blaine Tunnel to the St. Louis Tunnel. This would allow for more significant dilution of metals since the flows in the Dolores River are considerably higher. Seepage from the vicinity of the Blaine Tunnel adit continues to affect the mainstem of Silver Creek.

In order to mitigate the metals loading to Silver Creek, a significant amount of Colorado Voluntary Cleanup and Redevelopment Act (VCUP) work has been completed with the Argentine tunnel and tailings. ARCO has removed and/or stabilized or capped mine tailings that had been located in or adjacent to Silver Creek and the Dolores River. There remains a significant seep, however, originating at the tailings and running parallel to the creek where it eventually reaches a confluence with Silver Creek. This seep is a source of metals and a water quality concern. However, by addressing the Argentine Tailings Pile through the VCUP program, a "Super Fund" designation by the USEPA was eliminated and a potential remedy to the situation was created. Further downstream, as per an SEH (Short Elliott Hendrickson Inc.) study, there is an unnamed adit associated with the overhead tramway that also releases significantly degraded water quality into Silver Creek (King, 2006). This is identified as the "tramway adit" in this document.

V. INSTREAM CONDITIONS

Hydrology

The hydrograph of the Dolores River should approximate the pattern of a Silver Creek hydrograph except at a much larger magnitude. Such hydrographs are 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 or June, due to snowmelt that tails off through the summer (Figure 2, Table 3).

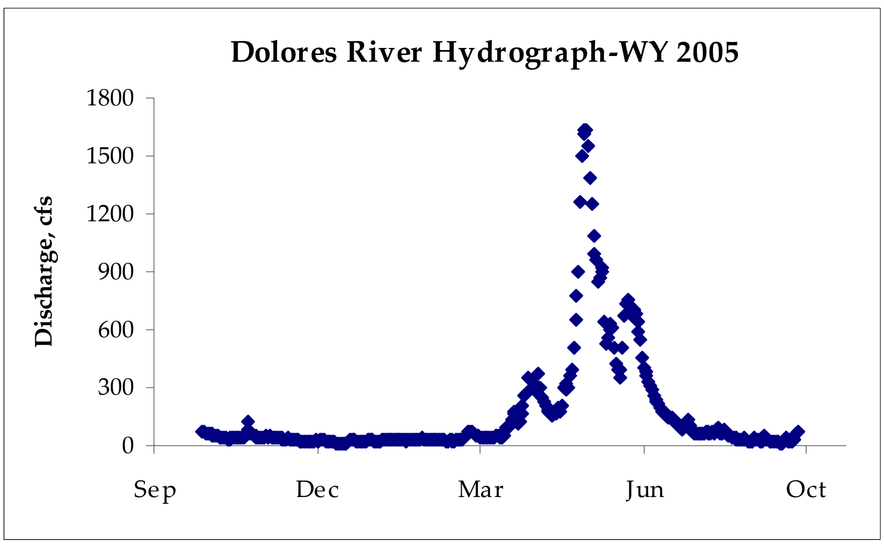

Figure 2. Hydrograph of Dolores River below the town of Rico, USGS gage 0916500.

Median monthly flows were estimated to be approximately between 0.3 and 124 cfs, based on estimated seasonal flows (USGS, 1999-2006). Monthly flow values were calculated by a power function outlined in Equation 1, with a resulting r^2 of 0.979.

(Eq. 1) $\text{Silver Creek Flow} = 0.0016 * (\text{Dolores River Flows}^{1.8087})$

The period of record for calculated flow measurements ranges from January 1999 to December 2006. Consequently, the data used to conduct the TMDL analysis includes a significant drought period (2002), but may not be reflective of considerable high flow periods.

	Monthly Median. Flow Dolores R.	Monthly Est. Median. Flow Silver Cr.	Acute 1E3 Silver Cr.	Chronic 30E3 Silver Cr.
Jan	16.5	0.3	0.1	0.1
Feb	18.0	0.3	0.1	0.1
Mar	31.0	0.8	0.1	0.1
Apr	144.5	12.9	1.4	0.3
May	504.5	123.8	3.6	0.8
Jun	227.0	29.2	0.4	0.3
Jul	60.5	2.7	0.2	0.2
Aug	55.5	2.3	0.1	0.2
Sep	44.5	1.5	0.2	0.2
Oct	38.0	1.2	0.2	0.3
Nov	23.0	0.5	0.1	0.1
Dec	18.0	0.3	0.1	0.1

Table 5. Monthly estimated median flows (cfs), for Silver Creek and observed Dolores River flows (January 99–December 2006).

Silver Creek flows were estimated from USGS gage #0916500 by Equation 1. 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 year. The use of low flows to calculate load reductions tends to overestimate loading reductions. Load allocations based on median flow are given in Appendix A.

As demonstrated by Figures 3 and 4, exceedance of the cadmium and zinc standards occurs throughout the entire range of flows. The variability in pollutant loading rates induced by hydrologic events may in fact have a beneficial effect on attainment of zinc water quality standards. Rainfall events, similar to snow melt, may lead to significant short term increases in pollutant concentrations; however, the dilution effect may counteract the increases in concentration (Figures 3 and 4).

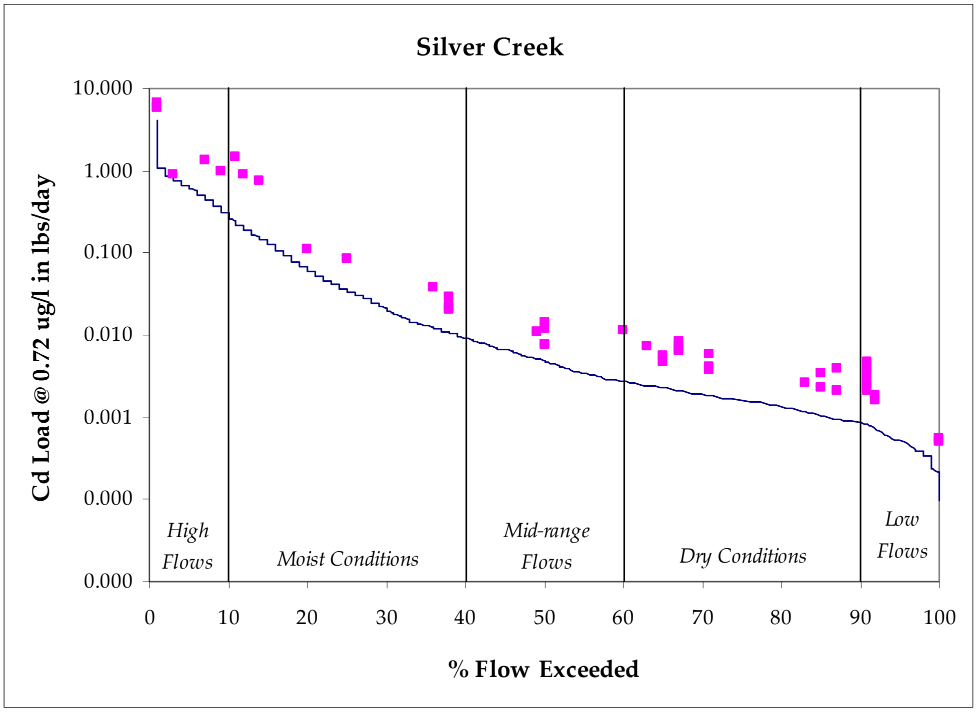

Figure 3. A flow duration curve for dissolved cadmium loads. The load duration curve approximates the cadmium load at an average TVS value of 0.72 ug/L.

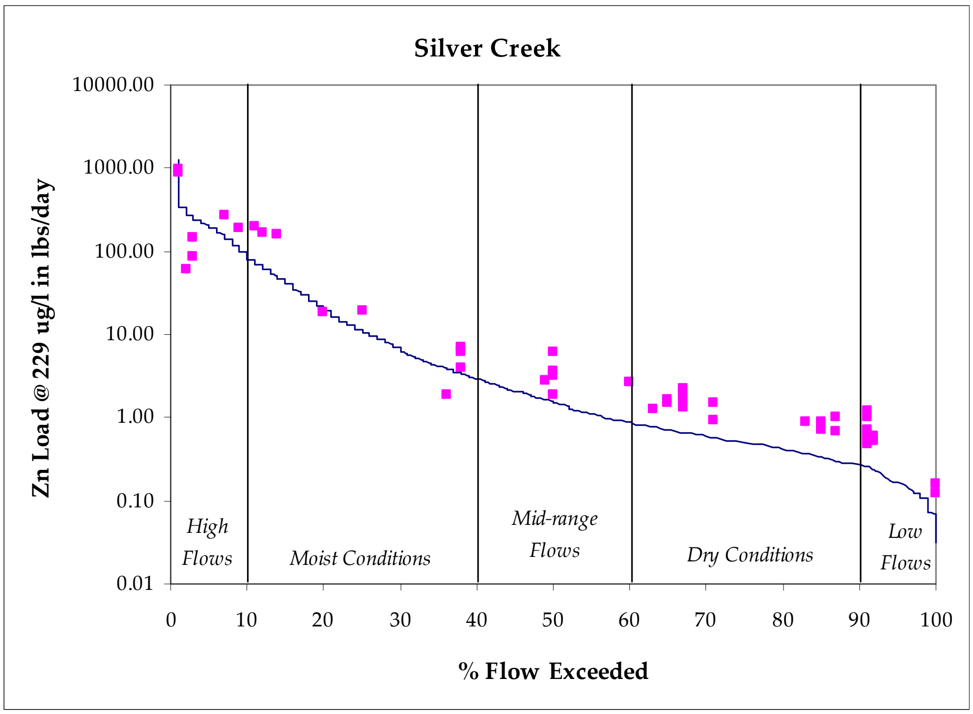

Figure 4. A flow duration curve for dissolved zinc loads. The load duration curve approximates the zinc load at an average TVS value of 229 ug/L.

Ambient Water Quality Data

To identify exceedances of the chronic water-quality standard, the average concentration of metals was calculated using the most current available data from SEH (Short Hendrickson Inc.) and CDPHE (Table 6). Sampling sites were located above and below the mining influence (Table 6). All of the available data was utilized for the TMDL analysis.

Station Number	No. of Samples	Period of Record	Source	Location
SVS 1	17	11/03 - 08/05	SEH	Silver Creek, just below town of Rico Water Supply Diversion
SVS 22	13	10/01 - 01/06	SEH	Silver Creek, just upstream of Argentine Tailings Seep
SVS 8	13	10/01 - 01/06	SEH	Silver Creek, below Argentine tailings, just below culvert outfall
SVS 20	10	10/01 - 01/06	SEH	Silver Creek, just above confluence with Dolores River
10780	49	05/92 - 05/06	WQCD	Silver Creek at Highway 145

Table 6. Locations of sampling sites, number and source of sample data, and period of record for data on Silver Creek, Segment 9.

Silver Creek first exceeded the standards for both cadmium and zinc just upstream of the Argentine Tailings Seep. Hardness values upstream of the Argentine Seep were approximately half that of downstream values. Data from site SVS-1, directly below the town of Rico's water supply diversion, however, demonstrates that Silver Creek does not exceed the water quality standards for either cadmium or zinc until immediately above the Argentine Tailings Seep (Table 7). Cadmium and zinc values exceed the standard beginning with site SVS-22. Site SVS-22 marks the beginning of the Argentine Tailings Seep (Figure 1). Dissolved cadmium and zinc values remain elevated throughout the remaining Silver Creek Segment.

Site	Avg. Hardness, mg/L	Cd-D, ug/L	Zn-D, ug/L
SVS-1	98	0.10	28.4
SVS-22	132	2.22	523.6
SVS-8	188	2.30	732.0
SVS-20	251	3.21	756.7

Table 7. Ambient water quality data for sites above and below abandoned mine influence. Concentrations represent 85^{th} % values.

Box and whisker plots demonstrate the variability between site locations on Silver Creek. Site SVS 1, Silver Creek just below the Rico water supply diversion, denotes background concentrations prior to mining influence. Dissolved cadmium and zinc concentrations remain elevated at the downstream sites (SVS 22, SVS 8, and SVS 20).

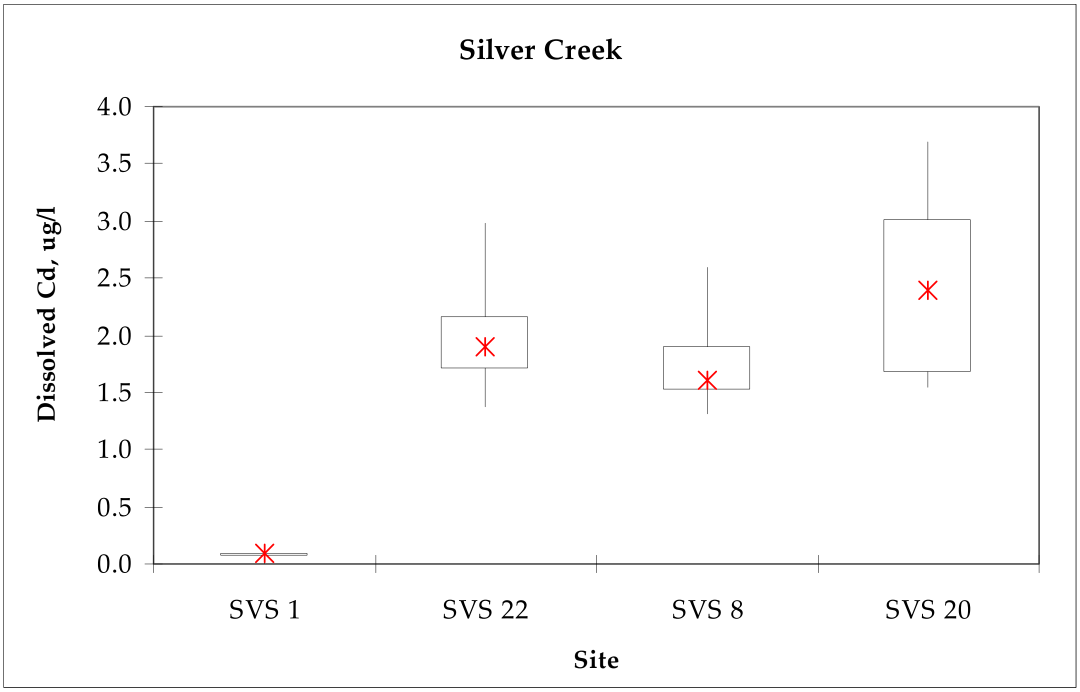

Figure 5. Box and whisker plot for dissolved cadmium for Silver Creek Segment 9. Boxes represent upper and lower quartiles (25^{th} and 75^{th}) while whiskers represent 5^{th} and 95^{th} percentiles. Red * indicates median values.

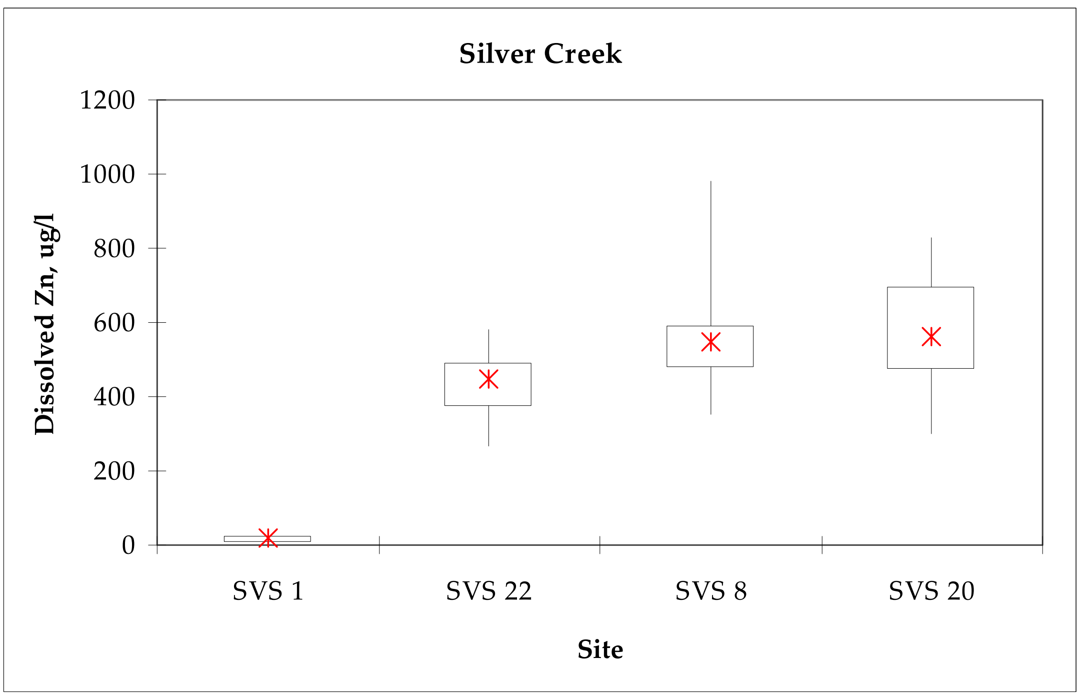

Figure 6. Box and whisker plot for dissolved zinc for Silver Creek Segment 9. Boxes represent upper and lower quartiles (25^{th} and 75^{th}) while whiskers represent 5^{th} and 95^{th} percentiles. Red * indicates median values.

Silver Creek Background					
	Avg. Hardness mg/L	Cd-D TVS	Cd-D, ug/L Observed	Zn-D TVS	Zn-D, ug/L Observed
Jan	122	0.49	0.10	147.3	21.4
Feb	123	0.50	0.10	148.3	30.0
Mar	136	0.53	0.06	161.6	39.9
Apr	89	0.39	0.10	112.6	18.4
May	57	0.28	0.09	77.0	8.5
Jun	55	0.27	0.00	74.7	0.0
Jul	75	0.34	0.04	97.3	4.3
Aug	95	0.41	0.09	119.0	8.5
Sep*	96	0.41	0.04	120.1	4.3
Oct	97	0.41	0.00	121.1	0.0
Nov*	126	0.51	0.10	151.4	30.0
Dec	104	0.44	0.10	128.5	18.5

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

Table 8. Ambient water quality data upstream of abandoned mine influence. Ambient cadmium and zinc concentrations are calculated as 85th% values.

Silver Creek Downstream of Mining Influence					
	Avg. Hardness mg/L	Cd-D TVS	Cd-D Observed	Zn-D TVS	Zn-D Observed
Jan	260	0.87	2.6	280.7	862.3
Feb	261	0.87	2.7	281.6	614.0
Mar	300	0.97	2.9	317.1	775.9
Apr	179	0.66	4.1	204.2	876.5
May	105	0.44	3.4	129.6	697.0
Jun	73	0.33	1.3	95.1	216.0
Jul	204	0.73	4.0	228.3	481.0
Aug	187	0.68	2.2	211.9	449.0
Sep	233	0.80	2.5	255.7	446.0
Oct	204	0.73	2.4	228.3	579.5
Nov	249	0.84	3.1	270.5	808.0
Dec	221	0.77	2.6	244.4	698.5

Table 9. Ambient water quality data downstream of abandoned mine influence. Ambient cadmium and zinc concentrations are calculated as 85th% values.

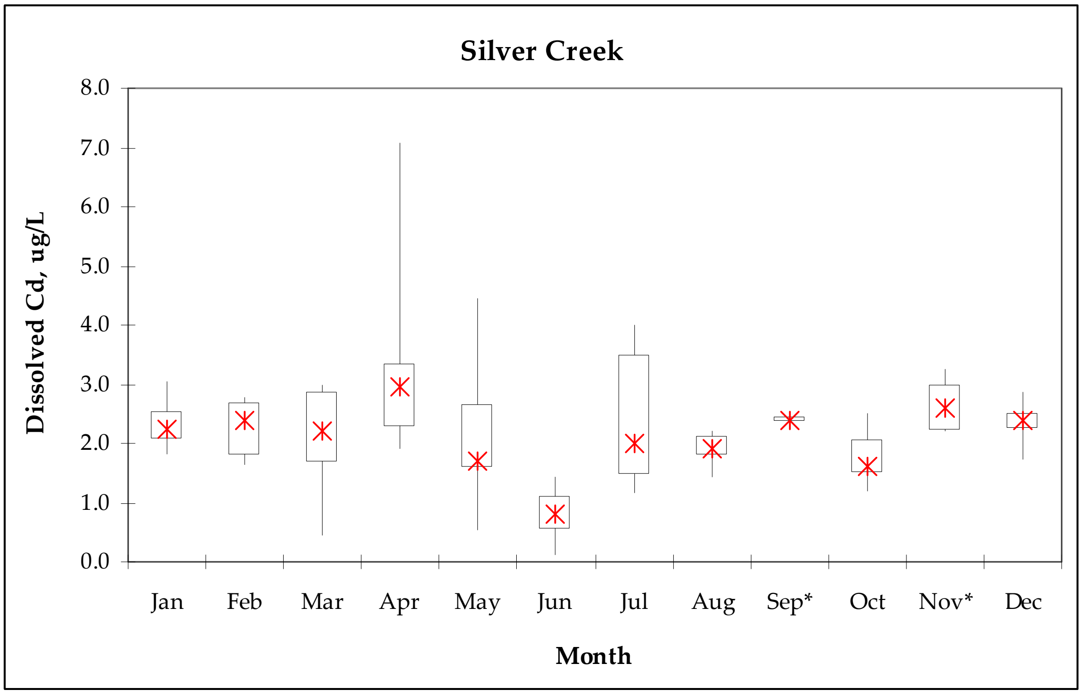

Figure 7. Box and whisker plot for dissolved cadmium for Silver Creek Segment 9 downstream of abandoned mine influence. Boxes represent upper and lower quartiles (25^{th} and 75^{th}) while whiskers represent 5^{th} and 95^{th} percentiles. Red * indicates median values.

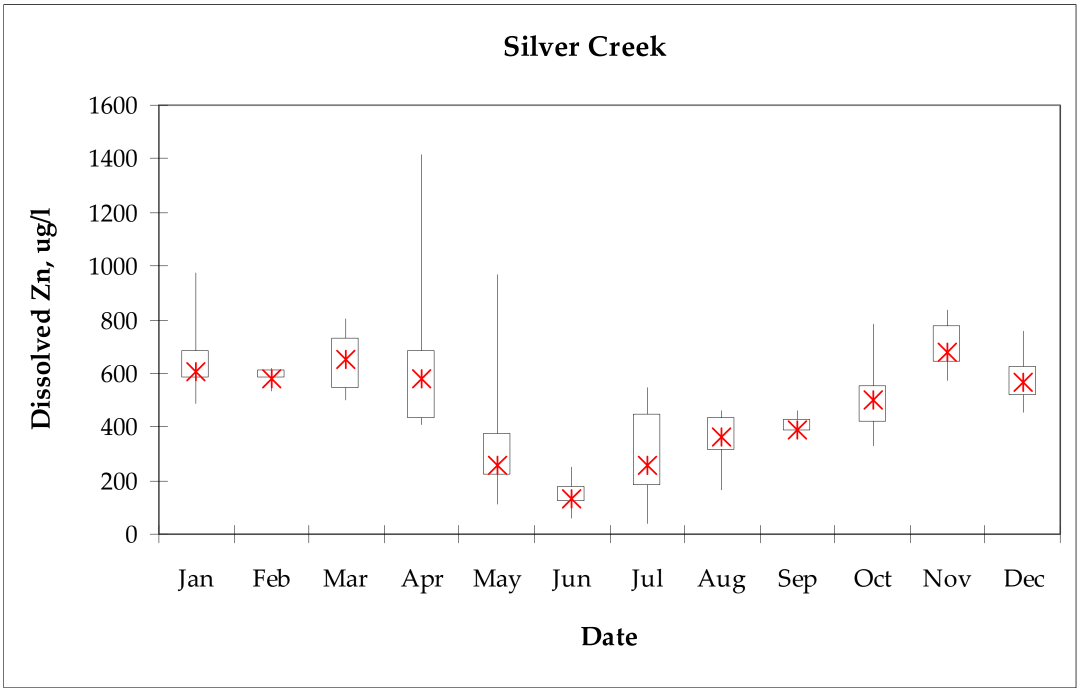

Figure 8. Box and whisker plot for dissolved zinc for Silver Creek Segment 9 downstream of abandoned mine influence. Boxes represent upper and lower quartiles (25^{th} and 75^{th}) while whiskers represent 5^{th} and 95^{th} percentiles. Red * indicates median values.

Box and whisker plots illustrate the variability between monthly data on Silver Creek. The months of May-July demonstrate the lowest median values, although April and May represent the highest variability in sample concentrations (figures 7 and 8). High median cadmium and zinc concentrations predominate in the low flow months of January through April (Figures 7 and 8).

VI. TMDL Allocation

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 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 no identified permitted dischargers to this segment actively discharging to Silver Creek Segment 9. Historic effects from the Rico Mining District however, are treated as non-permitted point sources in Segment 9 of this TMDL.

Load Allocations "(LA)"

Remaining background sources that were examined are considered non-point sources and are therefore accountable to load allocations.

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. A 10% explicit MOS is accounted for in the allocation section as a percentage of the overall allocation. 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 Silver Creek flow estimated from USGS gage #0916500 by Equation 1 multiplied by the existing stream standard and a conversion factor (0.0054) to approximate a load in pounds/day. 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. A conservative element is included with the use of chronic low flows and minimum monthly hardness values which approximates the critical condition in Silver Creek. Use of monthly minimum hardness also ensures that reductions necessary to attain chronic standards will also ensure attainment of acute standards. By incorporating the critical condition into the calculation of the TMDL, load reductions tend to be overestimated. Load allocations based on median flow are given in Appendix A. The incorporation of monthly TMDLs reflects the seasonality of cadmium and zinc load reductions in the Silver Creek watershed and more adequately reflect the current water quality situation.

Silver Creek Upstream of Abandoned Mine Influence (Background)									
	Min. Hardness** mg/L	Cd-D Observed, lbs/day	TMDL lbs/day	10% MOS	TMDL with a 10% MOS	TMDL LA lbs/day	TMDL WLA lbs/day	Reduction lbs/day	% Reduction
Jan	118	0.00005	0.0003	0.00003	0.0002	0.0002	0.000	-0.0002	0%
Feb	123	0.00005	0.0003	0.00003	0.0002	0.0002	0.000	-0.0002	0%
Mar	136	0.00003	0.0003	0.00003	0.0003	0.0003	0.000	-0.0002	0%
Apr	89	0.00016	0.0006	0.00006	0.0006	0.0006	0.000	-0.0004	0%
May	53	0.00037	0.0011	0.00011	0.0010	0.0010	0.000	-0.0006	0%
Jun	55	0.00000	0.0004	0.00004	0.0004	0.0004	0.000	-0.0004	0%
Jul	72	0.00005	0.0004	0.00004	0.0003	0.0003	0.000	-0.0003	0%
Aug	89	0.00009	0.0004	0.00004	0.0004	0.0004	0.000	-0.0003	0%
Sep*	93	0.00005	0.0004	0.00004	0.0004	0.0004	0.000	-0.0003	0%
Oct	97	0.00000	0.0007	0.00007	0.0006	0.0006	0.000	-0.0006	0%
Nov*	126	0.00005	0.0003	0.00003	0.0002	0.0002	0.000	-0.0002	0%
Dec	89	0.00005	0.0002	0.00002	0.0002	0.0002	0.000	-0.0001	0%
Mean:	95	0.00008	0.00045	0.00004	0.00040	0.00040	0.000	0.000	0%

*No data were available for this month. Value is an average of the previous and following monthly averages. Observed concentrations based on 85th% values of ranked data.
** Hardness values represent lowest observed monthly hardness values.

Table 10. Current background loading of cadmium in Silver Creek, upstream of abandoned mine influence. Loads were calculated using chronic low flows and USEPA DFLOW software.

The dissolved cadmium and zinc TMDL for the mainstem Silver Creek Segment 9, above the Argentine Tailings Pile includes a ten percent explicit Margin of Safety. Tables 10 and 11 demonstrate the TMDLs and current metals background load for cadmium and zinc, respectively. The TMDL is divided into both Waste Load and Load Allocations. Since there are no permitted dischargers or upstream mining features, sources that were examined were considered to be background, non-point sources and are therefore accountable to load allocations. No reductions are required for background sources.

Silver Creek Upstream of Abandoned Mine Influence (Background)

	Min. Hardness** mg/L	Zn-D Observed, lbs/day	TMDL lbs/day	10% MOS	TMDL with a 10% MOS	TMDL LA lbs/day	TMDL WLA lbs/day	Reduction lbs/day	% Reduction
Jan	118	0.012	0.077	0.008	0.070	0.070	0.000	-0.066	0%
Feb	123	0.016	0.080	0.008	0.072	0.072	0.000	-0.064	0%
Mar	136	0.022	0.087	0.009	0.079	0.079	0.000	-0.066	0%
Apr	89	0.030	0.182	0.018	0.164	0.164	0.000	-0.153	0%
May	53	0.037	0.313	0.031	0.281	0.281	0.000	-0.276	0%
Jun	55	0.000	0.121	0.012	0.109	0.109	0.000	-0.121	0%
Jul	72	0.005	0.101	0.010	0.091	0.091	0.000	-0.097	0%
Aug	89	0.009	0.122	0.012	0.109	0.109	0.000	-0.112	0%
Sep*	93	0.005	0.126	0.013	0.114	0.114	0.000	-0.122	0%
Oct	97	0.000	0.196	0.020	0.177	0.177	0.000	-0.196	0%
Nov*	126	0.016	0.082	0.008	0.074	0.074	0.000	-0.066	0%
Dec	89	0.010	0.061	0.006	0.055	0.055	0.000	-0.051	0%
Mean:	95	0.013	0.129	0.013	0.116	0.116	0.000	-0.116	0%

*No data were available for this month. Value is an average of the previous and following monthly averages. Observed concentrations based on 85th% values of ranked data.

** Hardness values represent lowest observed monthly hardness values.

Table 11. Current background loading of zinc in Silver Creek, upstream of abandoned mine influence. Loads were calculated using chronic low flows and USEPA DFLOW software.

Silver Creek Downstream of Abandoned Mine Influence									
	Min. Hardness** mg/L	Cd-D Observed*, lbs/day	TMDL lbs/day	10% MOS	TMDL with a 10% MOS	TMDL LA lbs/day	TMDL WLA lbs/day	Reduction lbs/day	% Reduction
Jan	142	0.0014	0.0003	0.00003	0.0003	0.0003	0.00001	0.0011	81%
Feb	148	0.0015	0.0003	0.00003	0.0003	0.0003	0.00001	0.0012	81%
Mar	155	0.0016	0.0003	0.00003	0.0003	0.0003	0.00001	0.0013	82%
Apr	106	0.0067	0.0007	0.00007	0.0006	0.0006	0.00001	0.0061	90%
May	66	0.0145	0.0013	0.00013	0.0012	0.0012	0.00002	0.0133	92%
Jun	59	0.0020	0.0005	0.00005	0.0004	0.0004	0.00001	0.0016	79%
Jul	120	0.0043	0.0005	0.00005	0.0005	0.0005	0.00001	0.0038	89%
Aug	102	0.0024	0.0005	0.00005	0.0004	0.0004	0.00001	0.0020	82%
Sep	180	0.0027	0.0007	0.00007	0.0006	0.0006	0.00001	0.0020	76%
Oct	131	0.0039	0.0008	0.00008	0.0008	0.0007	0.00002	0.0031	81%
Nov	153	0.0017	0.0003	0.00003	0.0003	0.0003	0.00001	0.0014	83%
Dec	104	0.0014	0.0002	0.00002	0.0002	0.0002	0.00000	0.0012	85%
Mean:	122	0.0037	0.0005	0.00005	0.0005	0.0005	0.00001	0.0032	83%

* Observed concentrations based on 85th% values of ranked data.

** Hardness values represent lowest observed monthly hardness values.

Table 12. Current background loading of cadmium in Silver Creek, downstream of abandoned mine influence. Loads were calculated using chronic low flows and USEPA DFLOW software.

Silver Creek Downstream of Abandoned Mine Influence

	Min. Hardness** mg/L	Zn-D Observed*, lbs/day	TMDL lbs/day	10% MOS	TMDL with a 10% MOS	TMDL LA lbs/day	TMDL WLA lbs/day	Reduction lbs/day	% Reduction
Jan	142	0.466	0.091	0.009	0.081	0.080	0.002	0.384	83%
Feb	148	0.332	0.094	0.009	0.084	0.083	0.002	0.247	75%
Mar	155	0.419	0.098	0.010	0.088	0.086	0.002	0.331	79%
Apr	106	1.420	0.212	0.021	0.190	0.187	0.004	1.229	87%
May	66	3.011	0.377	0.038	0.339	0.332	0.007	2.672	89%
Jun	59	0.350	0.128	0.013	0.116	0.113	0.002	0.234	67%
Jul	120	0.519	0.157	0.016	0.141	0.138	0.003	0.378	73%
Aug	102	0.485	0.137	0.014	0.123	0.120	0.002	0.362	75%
Sep	180	0.482	0.222	0.022	0.199	0.195	0.004	0.282	59%
Oct	131	0.939	0.253	0.025	0.228	0.224	0.005	0.711	76%
Nov	153	0.436	0.096	0.010	0.087	0.085	0.002	0.350	80%
Dec	104	0.377	0.069	0.007	0.062	0.061	0.001	0.315	83%
Mean:	122	0.770	0.161	0.016	0.145	0.142	0.003	0.625	77%

* Observed concentrations based on 85th% values of ranked data.

** Hardness values represent lowest observed monthly hardness values.

Table 13. Current background loading of zinc in Silver Creek, downstream of abandoned mine influence. Loads were calculated using chronic low flows and USEPA DFLOW software.

For the dissolved cadmium and zinc TMDL for the mainstem of Silver Creek Segment 9, below the Argentine Tailings Pile, a ten percent explicit Margin of Safety was included. Tables 12 and 13 list the TMDLs and current metals loads for cadmium and zinc, respectively. The TMDL is divided into both Waste Load and Load Allocations. The waste load allocation for the tunnels was determined first by calculating a background, or upstream concentration from the SEH sampling site SVS 1, Silver Creek just below the Town of Rico's water supply diversion. A concentration for downstream of the mine influence was also calculated. Downstream concentrations were a combination of sampling sites, SVS 8, SVS 20, SVS 22, and WQCD sampling site 10780, Silver Creek at Highway 145 (Table 6). The difference in upstream and downstream concentrations was attributed to mine influence. An annual average of the monthly contribution was then multiplied by the calculated TMDL to generate a WLA for abandoned mines. The percent reduction was calculated as the difference between the existing stream load (lbs/day) and the calculated TMDL (lbs/day) divided by the existing stream load. The annual percent contribution from abandoned mines was approximately 98% for both cadmium and zinc.

Cadmium load reductions are greatest in April and May, with load reductions ranging from 76% in September to 92% in May. The average annual loading reduction is approximately 83%. Loading reductions for zinc occur year round with required reductions ranging from 59% in September to as much as 89% in May.

Chronic monthly load reductions were applied to current ambient concentrations to assess acute standard attainment. The observed metals concentrations were adjusted to reflect the required monthly reductions. Adjusted acute values were then compared to acute standards on a sample by sample basis. Based upon the proposed loading reductions, all of the samples were found to be in attainment of the corresponding acute standard. Therefore, proposed loading reductions are protective of both chronic and acute toxic effects of cadmium and zinc.

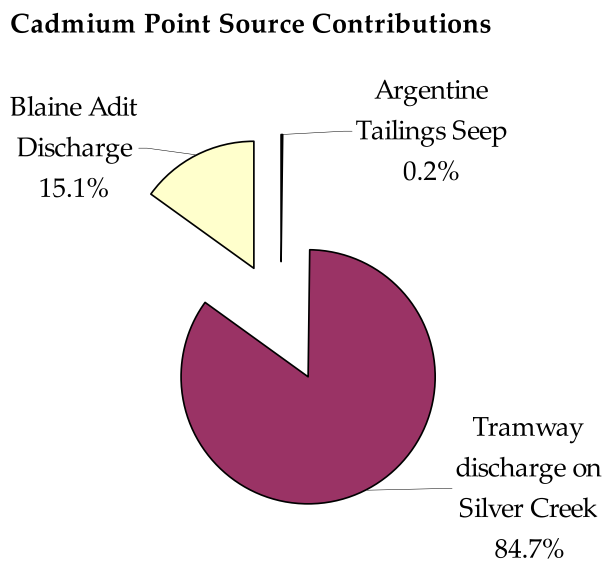

Figure 9. Cadmium percent contribution from non-permitted point sources.

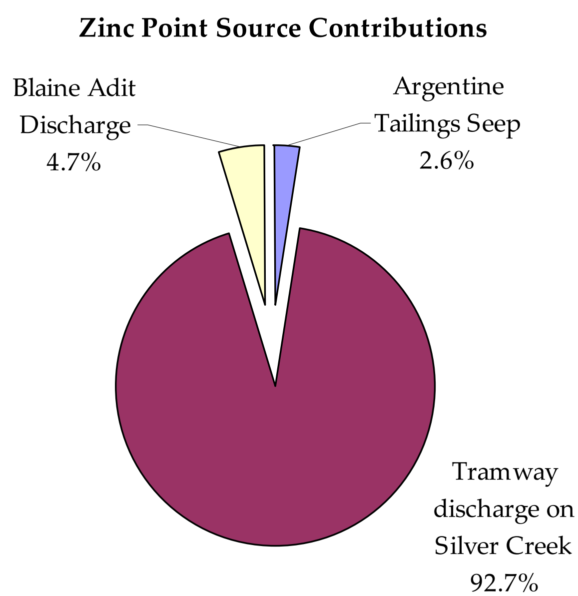

Figure 10. Zinc percent contribution from non-permitted point sources.

Data on the Argentine Tailings Pile directly and other seeps to Silver Creek are sparse. The most recent data are from 2005 and 2006. As demonstrated in Figures 9 and 10, the Tramway Discharge is the largest contributor to exceedances of table value standards in Silver Creek. The Tramway Discharge contributes approximately 85% of the cadmium load and 93% of the zinc load. The Blaine Adit Discharge contributes approximately 15% of the cadmium load and 5% of the zinc load to Silver Creek. The remainder of the cadmium and zinc load is associated with the Argentine Tailings Seep. Subsequently, a substantial reduction of both cadmium and zinc must be attained from the seeps/adits to reduce the metals load to Silver Creek.

VII. RESTORATION PLANNING AND IMPLEMENTATION PROCESS

The monthly percentages of loading reduction necessary to meet TVS standards for cadmium and zinc on Silver Creek are listed in Tables 10 and 11. The major sources contributing to the elevated level of metals in Silver Creek are the Argentine Tailings Seep, the Blaine Adit Discharge, and Tramway discharge. With the lack of monthly flow data available for Silver Creek, and the uncertainty of point source loading, it is difficult to appropriate loading reductions to each particular source. A substantial reduction of metals from these non-permitted point sources, however, is necessary to attain current TVS standards in Silver Creek. Additionally, there is no information regarding the flow contribution or water quality of the discharge from the Revenue Mine located on the south side of Silver Creek.

Previous Water Quality Improvements in the Watershed

Several Voluntary Cleanup Projects (VCUPs) were undertaken by ARCO to control mine tailings in the Silver Creek and Dolores River watersheds. A concrete barrier was installed in the Blaine Tunnel in the 1990's, and the flow was diverted through the St. Louis Tunnel and into the Dolores River. The increased flow in the Dolores River allows for a higher dilution of the discharged metals and a greater assimilative capacity, thus decreasing the metals load in Silver Creek.

Monitoring

In order to insure that the TMDL is adequately protective of the segment, monitoring of Silver Creek is required. Previous data were gathered at either high or low flow regimes, so a monthly flow analysis would be essential to fill in the data gaps for metals loading in Silver Creek. Additional monitoring of the Argentine Seep, Blaine Adit Discharge, and Tramway Discharge would also be beneficial. Additional aquatic life monitoring data would be useful to further document the current status of Silver Creek and the potential for restoration.

Conclusion

The goal of this TMDL is the attainment of the TVS for cadmium and zinc within Segment 9 of the mainstem of Silver Creek from a point immediately below the Town of Rico's water supply diversion to the confluence with the Dolores River. An average loading reduction of approximately 83% is necessary to reach the TMDL of 0.0005 lbs/day of cadmium. An average loading reduction of approximately 77% is necessary to reach the TMDL of 0.145 lbs/day for zinc.

Public Involvement

There has been a strong public participation in protecting and enhancing the water quality of Silver Creek and the Dolores River Watershed. The Town of Rico has been extensively involved in better understanding their water quality and quantity issues in order to better deal with historic mining impacts and impending growth and development.

A review and comment period was also made available to the public for 30 days. Each public comment received regarding the content of this document will be addressed. Comments and associated responses will be found in the final document.

The public has had an opportunity to be involved in the Water Quality Control Commission (WQCC) hearings, and 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 also has a public notice period for public involvement.

Public involvement was also achieved through collaboration with Karmen King and Grayling Environmental. Public participation will continue to promote future restoration of the watershed, as new remediation possibilities are explored.

A draft of these TMDLs was provided for public review and comment in October 2007. No comments were received at that time. These TMDLs were, however, revised per comments subsequently provided by USEPA. A second public comment period will be provided in April 2008.

IX. WORKS CITED

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