APPENDIX F – TARGET DEPARTURE ANALYSIS

Table of Contents

LIST OF TABLES

LIST OF FIGURES

F 1.0 INTRODUCTION

This appendix summarizes the departure of listed stream data from water quality targets and supplemental indicators described in **Section 5.4**. Water quality targets are the numeric criteria for chronic aquatic life (CAL), acute aquatic life (AAL) and human health (HH), contained in DEQ-7 (Montana Department of Environmental Quality, 2010) for metals and cyanide. Supplemental indicators include:

1. Numeric probable effects levels (PELs) for metals in stream sediments
2. Multi-metric index (MMI) and River Invertebrate Prediction and Classification System (RIVPACS) scores for macroinvertebrate samples
3. Water column sulfate concentration indicating the degree of sulfide mineral oxidation.

Map figures show the stream extent and (where possible) the locations of assessment and monitoring sites where the data originate. The precise locations and extent of mine facilities and features are illustrated in **Appendix A, Figure A-16** for the Zortman Mine area and **Figure A-17** for the Landusky Mine area.

To some degree, human influence has probably affected all streams in the planning area. However, a number of sites, selected by mining company or regulatory personnel, are intended to describe water quality with minimal mining influence. The analytical results from these "background" sites are compared to "existing" condition sites in order to illustrate the degree of departure from water quality criteria for each stream.

The target departure analysis for each stream also includes a discussion of the principal loading sources. These include geographic areas occupied by mine features such as waste rock repositories, leach pads, pad dikes, mine pits, abandoned mines. Sources also include water treatment process outfalls such as those for the Zortman, Landusky, and Swift Gulch Creek treatment plants.

The number of water quality analysis results varies widely by stream. Parameter-specific tables are used to summarize the criteria exceedance records of streams with large datasets. Each table gives the sample size, number of exceedances, and the exceedance rate percentages for each criteria comparison. The data are commonly reported with several method detection limits (MDLs) that have changed as analytical methods and laboratory equipment are upgraded. Earlier results have generally larger MDLs. Results with MDLs greater than the water quality criteria cannot be used in the departure analysis. Therefore, the sample size used to count chronic aquatic life exceedances may increase when counting exceedances of the larger acute aquatic life criteria. The sample sizes used to assess the departure from different criteria are identified in the "Sample Size" column of the summary tables. Single values for sample size appear in the "Sample Size" column where method detection limits have been low enough to assess departures from all water quality criteria.

Data departures are described in text rather than tables for small datasets or where a limited number of results dictate the need for TMDLs, as in the case of a single result that is twice the AAL criterion. Text is also used for datasets with a large number of homogenous results. This commonly applies to large numbers of results that are less than the MDLs.

The target departure analysis for hardness-dependent metals included only results with corresponding hardness values. Target departures are assessed for both high and low flow conditions. Where sufficient flow data is available, high and low flows are those greater or less than the median annual flow. Most of

the datasets lack flow data. In these cases, high flow records are those for samples collected during the months of April, May and June; low flow samples are those during July through March. The raw data used in the departure analysis is contained in **Appendix B**.

F 2.0 TARGET DEPARTURES BY STREAM

F 2.1 ALDER GULCH (MT40E002_050)

Alder Gulch is listed as impaired in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) for cadmium, copper, lead, mercury, selenium, zinc, and pH. The segment is classified as C-3 and extends for 4.04 miles from its headwaters to its confluence with Ruby Gulch. Current water quality conditions are represented by sites Z-2, Z-8, and Z-16 (**Figure F-1**.)

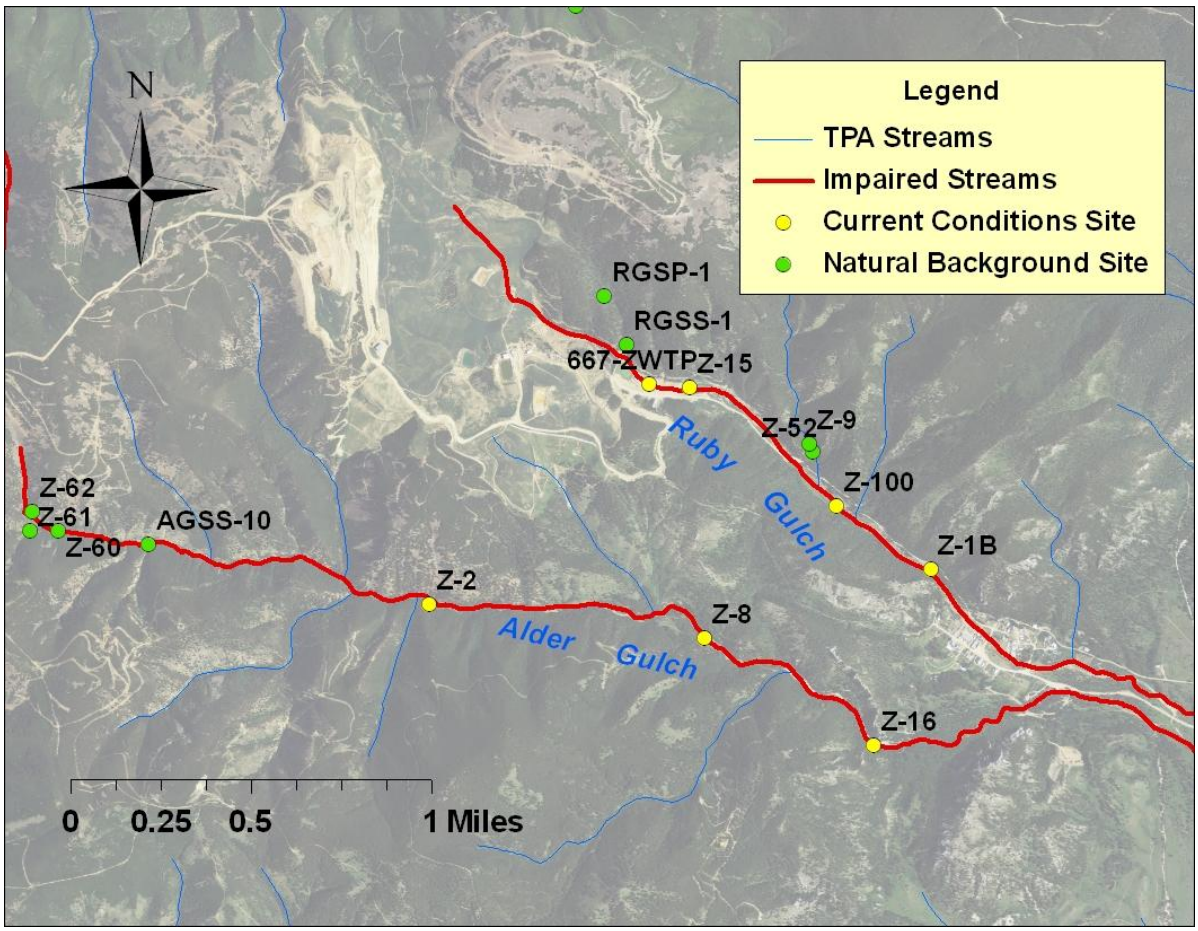

Figure F-1. Alder and Ruby gulches and locations of current condition and natural background sites.

F 2.1.1 Alder Gulch Sources

Placer mining first occurred in Alder Gulch during the 1880s. Historic load mining sources include the abandoned Hawkeye Mine located south of Alder Gulch in an unnamed tributary south of site AGSS-10 (Rossillon, 1991). Mine pits, a large waste rock dump, several leach pads, and supporting dikes of the Zortman Mine occur in northern Alder Gulch tributaries of Carter Gulch and Alder Spur. The eastern

branch of Carter Gulch contains the Alder Gulch Waste Rock Repository which contains 2.3 million cubic yards of material removed from Zortman Mine pits. The Carter Gulch Seepage Capture System, that collects nearly 10 million gallons of ARD per year, was located at the toe of this dump until destroyed after a May 21, 2011, landslide at the toe of the dump. East of Carter Gulch is Alder Spur, an ephemeral Alder Gulch tributary that contains the Alder Spur Seepage Capture System. The capture system is below the Z83 and Z84 leach pads and supporting dikes. Alder Spur may also receive drainage from the Z82 and Z76/81 leach pads located on the drainage divide between Alder Spur and Ruby Gulch.

The Alder Gulch dataset includes water column chemistry for comparison with Circular DEQ 7 human health (HH), acute aquatic life (AAL), and chronic aquatic life (CAL) criteria for surface waters. The age of the data ranges from 1978 to 1998 for sites Z-2 and Z-8, and 1990 to 1996 for site Z-16. The water column criteria exceedance records are summarized in the tables below for each metal impairment cause.

Monitoring sites Z-60, Z-61, Z-62, and AGSS-10 in upper Alder Gulch are selected as representing natural background water quality conditions. The sites were established from 1996 to 1998 to describe water quality with minimal mining effects.

F 2.1.2 Alder Gulch Parameter Departures

Cadmium (Cd)

There are 68 cadmium results for the three current condition monitoring sites. The values range from less than 0.1 to 172 µg/L. However, the method detection limit (MDL) for 25 records exceeds the CAL criterion and MDLs for two samples exceed the AAL criterion. Of the 43 cadmium results that can be compared to the CAL criteria, there are 26 exceedances. Of 66 results that can be compared to the AAl criteria, there are 17 exceedances. The HH criterion of 5 µg/L is exceeded in 19 samples. The number of cadmium criteria exceedances and exceedance rates, expressed as percentages, are given in **Table F-1** by flow condition.

Table F-1. Cadmium criteria exceedance numbers and percentages by flow condition in Alder Gulch

Flow Condition	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	18/32/34	11	61	9	28	6	18
Low Flow	25/34/34	15	60	7	19	7	21
All Flows	43/66/68	26	60	17	25	13	19

Seven Cd results are available from the four background sites under flow conditions ranging from 3-40 gallons per minute (gpm). Six results have MDLs less than the CAL criterion. One of these six exceeded the CAL during high flows. No natural background sites exceeded the AAL criteria. Therefore, there is potential for natural background Cd concentrations to exceed CAL criteria during high flows.

For the current condition sites, exceedance percentages were greater than 10 for both aquatic life criteria. The high aquatic life exceedance rates, plus the HH exceedances indicated the need for an Alder Gulch cadmium TMDL.

Copper (Cu)

There are 66 copper results for sites Z-2, Z-8, and Z16, ranging from less than 1 to 2,010 µg/L. Fifty-eight results had MDLs small enough for comparison with CAL criteria. Twenty-one (36%) exceeded CAL

criteria and 16 of 63 results (25%) exceeded AAL criteria. The record contains a single low flow HH exceedance. High flow exceedances were roughly double those occurring during low flows. The number of copper criteria exceedances and exceedance rates, expressed as percentages, are given in **Table F-2** by flow condition.

Table F-2. Copper criteria exceedance numbers and percentages by flow condition in Alder Gulch.

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	27/31/33	15	56	11	35	0	0
Low Flow	31/32/33	6	19	5	16	1	3
All Flows	58/63/66	21	36	16	25	1	2

Seven copper results obtained during May and June of 1996 and 1997 are available from sites Z-60, Z-61, Z-62, and AGSS-10 representing natural background concentrations. Except for site AGSS-10, all results exceed both CAL and AAL criteria. Only the CAL criterion was exceeded at AGSS-10. The results indicate that natural background copper concentrations in upper Alder Gulch may commonly exceed the aquatic life criteria. There were no HH exceedances among the data from the background sites.

Among the current condition sites, both CAL and AAL exceedance rates are greater than 10 percent under both flow conditions. The high exceedance rates plus the HH exceedance indicate the need for a copper TMDL in Alder Gulch.

Lead (Pb)

There are 69 lead results for sites Z-2, Z-8 and Z-16 that have corresponding hardness values. Many the results have MDLs that exceed the CAL target criteria. Therefore, the useful sample size for CAL comparisons is smaller than than those for AAL and HH. The lead values range from less than 2 to 30 µg/L. **Table F-3** gives the sample size, number of criteria exceedances and exceedance rates, expressed as percentages, for lead in Alder Gulch.

Table F-3. Lead criteria exceedance numbers and percentage rates under high and low flow conditions in Alder Gulch.

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	23/36/36	12	52	0	0	4	11
Low Flow	29/33/33	3	10	0	0	4	12
All Flows	52/69/69	15	29	0	0	8	12

Lead concentration data for the four natural background sites were all less than the MDL of 3 µg/L. This MDL is greater than the applicable CAL criterion of 1.0 µg/L, so compliance with the CAL criterion could not be determined. None of the results from natural background sites exceeded either the AAL or HH criteria.

The exceedance rates for the CAL criteria are greater than 10 percent and the record contains HH exceedances. Therefore, a lead TMDL is required for Alder Gulch.

Mercury (Hg)
The mercury dataset for Z-2, Z-8 and Z-16 includes 52 results with a single positive detection of 0.2 µg/L in a sample collected on May 14, 1991, from Alder Gulch below the confluence with Alder Spur. The remaining sample results are all less than MDLs that range from 0.2 to 2.0 µg/L. All mercury results are reported with MLDs greater than the HH criterion of 0.05 µg/L. The uncertainty introduced by the high MDLs, the previous listing for mercury, and the age of the data (1990-1997) indicate the need for a mercury TMDL in Alder Gulch.

Selenium (Se)
There are 71 analytical results for selenium among the three current condition sites. The data were collected from 1990 to 1998 and contain four positive detections. A single result of 184 µg/L on October 14, 1992, exceeded both aquatic life criteria and the HH criterion (50 µg/L) under high flow conditions. The three subsequent positive detections were all less than the CAL criterion of 5 µg/L.

The seven selenium results available for the four natural background sites are all less than the MDL of 1 µg/L, under a combination of high and low flow conditions. The selenium result of 184 µg/L is more than twice the AAL criteria (20 µg/L), exceeds the HH criterion and indicates the need for a selenium TMDL for Alder Gulch.

Zinc (Zn)
The zinc dataset contains 78 results ranging from less than 10 to 3,650 µg/L. All MDLs are less than the surface water Zn criteria. **Table F-4** gives the sample size, number of criteria exceedances and exceedance rates, expressed as percentages, for zinc in Alder Gulch.

Table F-4. Zinc criteria exceedance numbers and percentage rates under high and low flow conditions in Alder Gulch.

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	39	10	26	10	30	0	0
Low Flow	39	7	18	7	16	2	5
All Flows	78	17	22	17	22	2	3

There were no aquatic life or human health criteria exceedances among nine Zn results obtained under both high and low flow conditions at the four natural background sites. The high exceedance rates for both CAL and AAL criteria and the occurrence of HH exceedances indicate the need for a zinc TMDL in Alder Gulch.

F 2.1.3 Alder Gulch Supplemental Indicators

Sulfate
There are no sediment chemistry or macroinvertibrate metric data available for Alder Gulch. **Figure F-2** is a graph of sulfate concentrations for the three current condition monitoring sites. Sites Z-2 and Z-8 have records over the course of ZMI mining activity. Site Z-16 was sampled eight times between 1990 and 1996. The spike in sulfate coincides with completion of the Alder Gulch Waste Rock Repository in Carter Gulch. The surface of the repository was regraded in 1992 and the Carter Gulch and Alder Spur capture systems installed in 1997. The sulfate concentrations measured farthest downstream (Z-16) are similar to those at the start of ZMI mining. Farther upstream, elevated sulfate persisted later at sites

closer to the waste rock and leach pad sources. Sulfate concentrations in Alder Gulch indicate the effects of ARD.

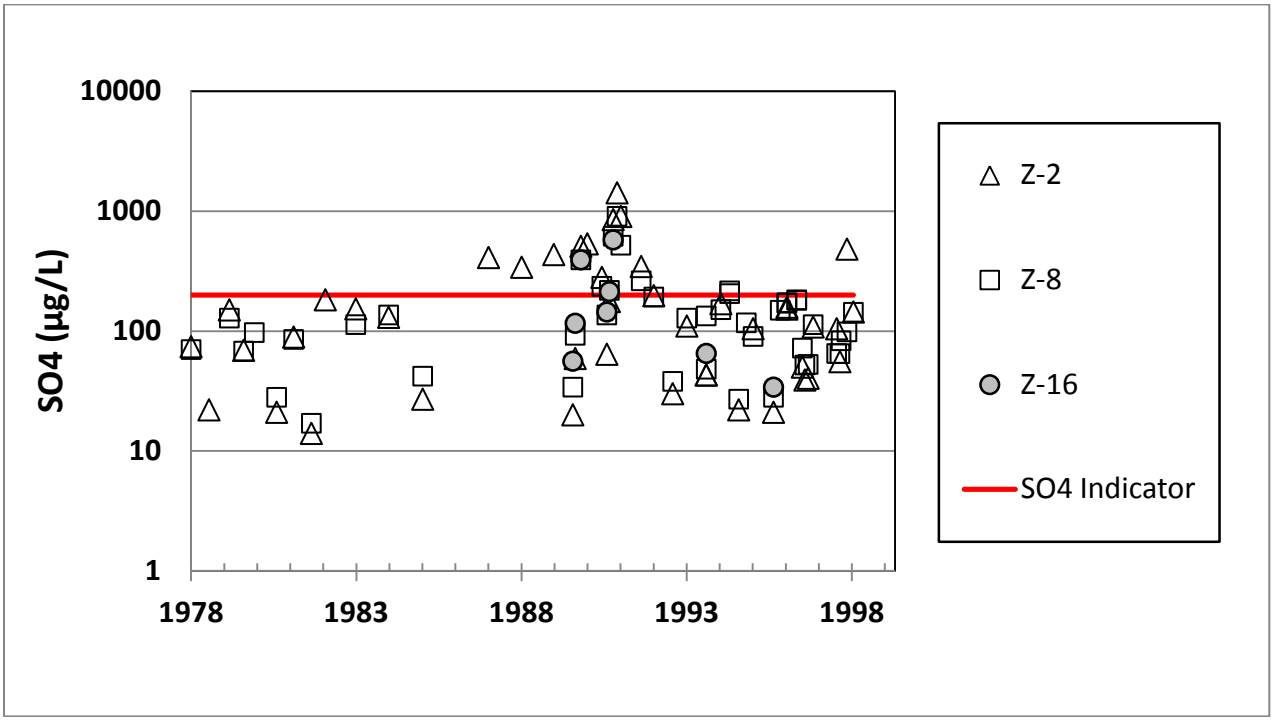

Figure F-2. Sulfate monitoring record for sites Z-2, Z-8, and Z-16 in Alder Gulch.

The sulfate data record combined with recent damage to the Carter Gulch capture system after partial failure of the Alder Gulch Waste Rock Repository suggest that mining sources are continuing to cause elevated metals loading to Alder Gulch.

F 2.1.4 Alder Gulch TMDL Development Conclusions

Elevated aquatic life criteria exceedance rates, combined with HH health exceedances support TMDL development for cadmium, copper, lead, and zinc. Cadmium will serve as a surrogate parameter to address the pH listing for Alder Gulch

The current Hg listing, past mercury placer mining sources in Alder Gulch, and age of the data record combine to require a Hg TMDL for Alder Gulch. A single selenium result exceeding the aquatic life and HH criteria, the previous selenium listing, and the lack of recent selenium data combine to require a selenium TMDL in Alder Gulch.

F 2.2 BEAVER CREEK (MT40M001_011)

Beaver Creek was listed as impaired in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) for cadmium, iron, and lead. The segment is classified as B-3 and extends for 5.4 miles from its headwaters in the Little Rockies, northeastward to the Fort Belknap Reservation boundary. Current water quality conditions are represented by the records for sites Z-31, Z-39, and M41BEVRC03 (**Figure F-3**). Site Z-27, assumed to represent natural background conditions, is located in an ephemeral headwater tributary of Beaver Creek with no discernable mining sources. Site Z-30 is in the Lodge Pole Creek drainage to the west of Beaver Creek.

F 2.2.1 Beaver Creek Sources

The topography of Shell Butte separates the Beaver Creek drainage from the area disturbed by the Zortman Mine. Three abandoned mines occur in Beaver Creek. The Beaver Mine is in an ephemeral draw about 1,500 feet upslope and north of monitoring site Z-39 (**Figure F-3**). Mine features include a collapsed adit and un-vegetated spoils that are a conceivable source of metals in sediment. Two small mine disturbances occur on a topographic bench about 1,600 feet south of the stream channel at site Z-31. No features of either site are visible on aerial photographs and their influence on water quality is assumed to be minor. Placer mining occurred intermittently in the Little Rockies from the 1880s to about 1940 and the Beaver Creek alluvium was probably placer mined to some extent. No obvious evidence of placer mining was seen during the 2005 DEQ assessment.

A recreation road parallels the stream for most of its length. Recent traffic has been restricted to all-terrain vehicles. An access road from the Zortman Mine crosses the recreation road near site Z-39. Roadway segments near the stream are potential sources of runoff and sediment-bound metals.

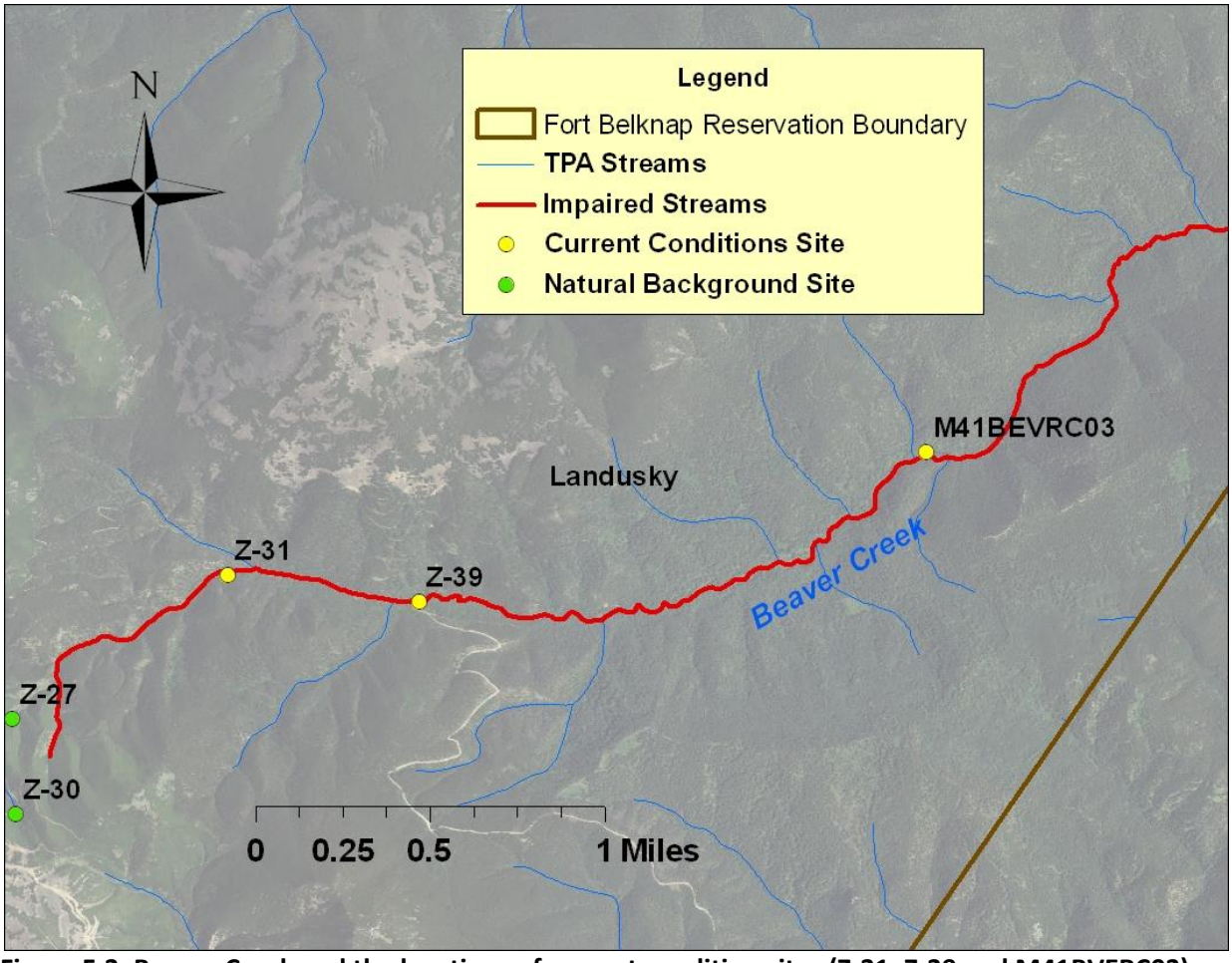

Figure F-3. Beaver Creek and the locations of current condition sites (Z-31, Z-39 and M41BVERC03) and natural background site Z-27

The Beaver Creek dataset for current conditions includes 19 water column chemistry records collected from 1990 to 1997 at site Z-31, 8 records for site Z-39 collected from 1994 to 1997, and 1 sample

collected during a DEQ assessment at site M41BEVRC03 in July of 2005. One sediment chemistry sample and one macroinvertebrate sample were collected during the DEQ assessment. Site Z-27 has water column chemistry data for 26 sampling events between 1990 and 2001.

F 2.2.2 Beaver Creek Parameter Departures

Cadmium

Table F-5 contains the water column cadmium exceedance summary for Beaver Creek for the three current condition sites. Seventeen cadmium results are available for the three sites. The MDL of 1 µg/L was too high to assess compliance with CAL criteria for eight results. The two CAL and AAL exceedances both occurred during high flow conditions on May 29, 1990. All samples since 1990 have contained less than detectable concentrations of cadmium.

Table F-5. Cadmium criteria exceedance numbers and percentage rates under high and low flow conditions in Beaver Creek.

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	7/11/11	2	29	2	18	0	0
Low Flow	2/6/6	0	0	0	0	0	0
All Flows	9/17/17	2	22	2	12	0	0

No HH criteria were exceeded at the three current condition sites. Although the exceedance rates are greater than 10 percent for both the CAL and AAL criteria, the water quality trend is clearly toward improvement. Since the two positive detections in 1990, no cadmium analysis using adequate MDLs has exceeded any drinking water or aquatic life criteria.

The data record for site Z-27 contains 18 results for total recoverable cadmium. Five results have MDLs that exceeds the CAL criteria. Of the 13 remaining cadmium results, one high flow sample (on May 29, 1990) exceeded both aquatic life criteria and a second high flow sample in 1994 exceeded the CAL criterion. The 11 remaining samples, including the 10 most recent, have all met target criteria. The lack of human-caused sources at Z-27 is evidence that natural background cadmium concentrations may occasionally exceed aquatic life criteria during high flows. Despite the CAL and AAL exceedance rates for cadmium, the improving water quality trend warrants further monitoring rather than TMDL development at this time.

Iron (Fe)

There are 17 results for iron among the three current condition sites. All are below the 1,000 µg/L aquatic life criteria. Site Z-27, representing natural background conditions, has 15 iron results with one CAL exceedance in May of 1994. The data did not indicate that iron is affecting beneficial uses in Beaver Creek.

Lead

The dataset for lead in Beaver Creek consists of 10 high flow and 6 low flow results with corresponding hardness values. High MDLs prevent the use of several results in assessing compliance with the CAL criteria. All but the 2005 result from site M41BEVRC03 are dated from 1990 to 1997. The compliance record for lead in Beaver Creek is summarized in **Table F-6** for the three current conditions sites.

Table F-6. Lead criteria exceedance numbers and percentage rates under high and low flow conditions in Beaver Creek

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	6/10/10	3	50	0	0	3	30
Low Flow	3/6/6	0	0	0	0	0	0
All Flows	9/16/16	3	33	0	0	3	19

The dataset includes three HH exceedances and three CAL exceedances, all occurring during high flows. AAL criteria were not exceeded in any sample. The CAL and HH exceedances indicate that a TMDL for lead is needed in Beaver Creek.

There are 18 lead results in the dataset for site Z-27. Nine results have MDLs low enough to assess CAL compliance and five of the nine exceed the CAL criteria. No samples among 18 exceed the AAL. Three results exceed the HH criterion. Considering the remoteness of the site from sources, the results suggest that natural background lead concentrations in Beaver Creek will occasionally exceed the most restrictive water quality criteria under both high and low flow conditions. The CAL exceedance rate of 33 percent and three HH exceedances indicate the need for a lead TMDL in Beaver Creek.

F 2.2.3 Beaver Creek Supplemental Indicators

Sulfate

There are 22 sulfate analysis results available from the three current condition sites and 17 results from site Z-27. All are less than the supplemental indicator value of 200 mg/L. The median concentration at current condition sites is 6.6 mg/L; the median concentration at site Z-27 is 5 mg/L.

Macroinvertebrate Metrics

The low valley MMI metric for the sample collected at site M41BEVRC03 is 54, compared to the minimum aquatic life use support value of 48. The metric does not indicate impairment of aquatic life uses.

Sediment Metals

The sediment sample from site M41BEVRC03 contained less than the MDL (0.5 µg/g) for cadmium. The lead concentration in the sediment sample (16.2 µg/g) is less than the NOAA recommended PEL of 91.3 µg/g. The iron concentration in the sediment sample was within the NOAA criterion of two percent.

F 2.2.4 Beaver Creek TMDL Development Conclusions

The cadmium listing for Beaver Creek may have resulted from samples collected on a single day, May 29, 1990. The 17 water samples collected from all four sites between 1996 and 1998 meet all target criteria during both high and low flows. Considering the age of the data, the lack of recent exceedances, and the possibility that natural background sources during high flows may exceed the most restrictive criteria, additional monitoring is a reasonable alternative to TMDL development for cadmium in Beaver Creek.

With the water quality exceedance rate at less than 10 percent, and no elevated iron detected in sediment, the iron records in Beaver Creek do not support development of an iron TMDL.

Three of nine lead values (33%) with sufficiently high MDLs exceed the CAL criteria and three HH criteria exceedances indicate the need for a lead TMDL.

F 2.3 South Big Horn Creek (MT40I001_030)

South Big Horn Creek impairment causes in the 2010 Integrated Report included aluminum, arsenic, cadmium, nickel, and zinc. The segment is classified as B-1 and extends for 1.4 miles from its headwaters, westward to the Fort Belknap Reservation boundary. Current water quality conditions are represented by the records for sites L-48 and L-48A (**Figure F-4**). Site L-21 is located just upstream of the confluence with Swift Gulch Creek. Human-caused sources are not evident in the South Big Horn Creek drainage above the Swift Gulch Creek confluence. Therefore, site L-21 conceivably represents natural background conditions in South Big Horn Creek. Sites L-49 and M37SWFGC01 in **Figure F-4** are on Swift Gulch Creek.

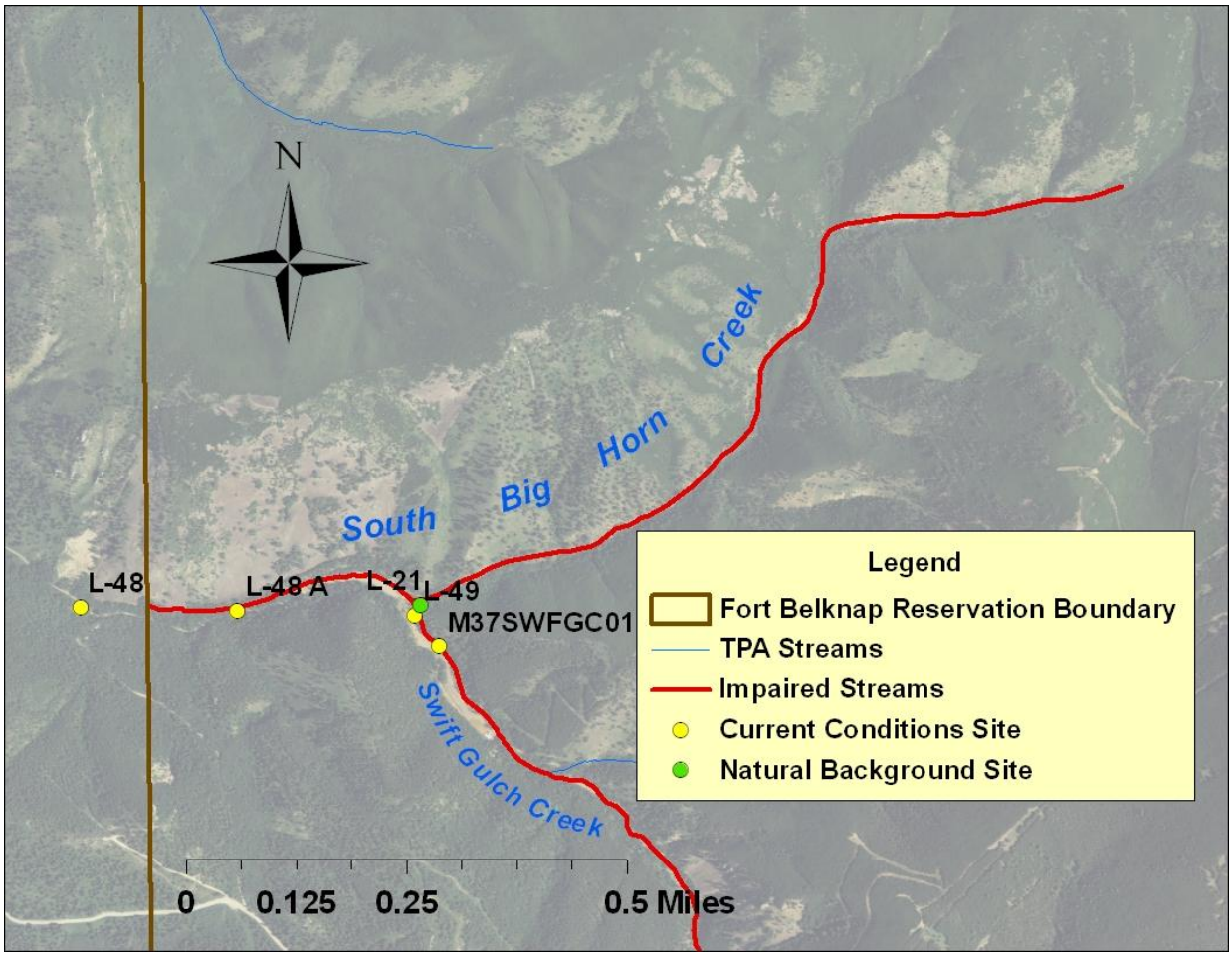

Figure F-4. South Big Horn Creek extending from the northeast, past the Swift Gulch Creek confluence, to the Fort Belknap Reservation boundary

F 2.3.1 South Big Horn Creek Sources

Evidence of placer mining occurs along the reach of South Big Horn Creek below the Swift Gulch Creek confluence. Other sources are downstream effects of ARD impacts to Swift Gulch Creek associated with the mine pit complex at the Landusky Mine.

F.2.3.2 South Big Horn Creek Parameter Departures

Aluminum

Six aluminum results in the pH range of 6.5-9.0 are available for sites L-48 and L-48A. Four have MDLs low enough to assess CAL compliance and one of these (25% of the total) exceeds the 87 µg/L CAL criterion. No sample exceeds the AAL criterion of 750 µg/L. The aluminum record for sites L-48 and L-48a is summarized in **Table F-7**. The CAL exceedance rate of 25 percent indicates the need for an aluminum TMDL.

Table F-7. Aluminum criteria exceedance numbers and percentage rates under high and low flow conditions at sites L-48 and L-48A in South Big Horn Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance	
		Number	%	Number	%
High Flow	0	0	0	0	0
Low Flow	4	1	25	0	0
All Flows	4	1	25	0	0

Thirteen aluminum analysis results, reported with an MDL of 100 µg/L, are available for background site L-21. These include two positive high flow detections in 1996 and 1997. The positive detections are followed by three results dating from May through August of 1997, and a series of eight samples collected during August 2008. All results since April, 1997, under both high and low flow conditions, have contained less than detectable amounts of aluminum. Assuming a concentration of 50 µg/L in samples containing less than the MDL, 50 µg/L becomes the median aluminum concentration at site L-21. This value is selected as the natural background concentration of aluminum in South Big Horn Creek.

Arsenic

There are 97 results for arsenic available for sites L-48 and L-48A. Over 70 percent of the results have been less than the 3 µg/L MDL. The record contains a single HH exceedance (33 µg/L) that occurred in a high flow sample in May of 2004. No HH exceedances have occurred in 88 subsequent samples from the two sites. Arsenic has not been detected in 33 samples collected at site L-21 from 1986 through 2008. No arsenic aquatic life criteria have been exceeded in any South Big Horn Creek sample. However, the 2004 HH criterion exceedance triggers the need for an arsenic TMDL in South Big Horn Creek.

Cadmium

The cadmium dataset for sites L-48 and L-48A contains 92 results obtained from 1997 through 2010. The cadmium exceedance record is summarized in **Table F-8**. The MDLs used for cadmium analysis have been low enough to allow comparisons with both aquatic life and human health criteria. Therefore, a single sample size value appears in the table for each flow condition.

Table F-8. Cadmium criteria exceedance numbers and percentage rates under high and low flow conditions at sites L-48 and L-48A in South Big Horn Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	42	26	62	0	0	0	0
Low Flow	50	34	68	0	0	4	8
All Flows	92	60	65	0	0	4	4

The CAL criteria have been consistently exceeded at the current condition sites under variable flows. There are no exceedances of the AAL criteria. The four exceedances of the HH criteria have all occurred under low flow conditions since 2007. At site L-21, two CAL exceedances occurred in 23 samples (9%) with sufficiently low MDLs. No AAL or HH exceedances occurred in any of 31 samples from site L-21. The data suggest that natural background concentrations of cadmium may occasionally exceed water quality criteria. The rate of CAL exceedances (65%) and the four HH criterion exceedances require a TMDL for cadmium.

Iron (Fe)

South Big Horn Creek was not listed for iron in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010). However, the data records for sites L-48 and L-48A contain 22 exceedances of the 1,000 µg/L CAL criteria among 100 samples collected between 2002 and 2011. All but one exceedance occurred during high flows. There are three iron exceedances among 37 Fe results at site L-21, indicating that natural background iron is occasionally elevated. The median iron concentration at Z-21 during high flow is 130 µg/L, and 12 µg/L during low flows. The aquatic life exceedance rate of 22 percent among current condition sites justifies an iron TMDL in South Big Horn Creek.

Nickel (Ni)

There are 98 records for nickel analysis for sites L-48 and L-48A. The exceedance record is summarized in **Table F-9**. No HH or aquatic life criteria for nickel were exceeded in any of 31 samples collected at site L-21.

The nickel dataset for existing condition sites has CAL criteria exceedance rates greater than 10 percent and numerous HH exceedances. A nickel TMDL is required for South Big Horn Creek.

Table F-9. Nickel criteria exceedance numbers and percentage rates under high and low flow conditions at sites L-48 and L-48A in South Big Horn Creek

		CAL Exceedance		AAL Exceedance		HH Exceedance	
Flow Conditions	Sample Size	Number	%	Number	%	Number	%
High Flow	45	5	11	0	0	5	11
Low Flow	53	9	17	0	0	15	28
All Flows	98	14	14	0	0	20	20

Zinc

There are 91 zinc analysis results for sites L-48 and L-48A dating from 1997 through 2010. The zinc exceedance record is summarized in **Table F-10**.

Table F-10. Zinc criteria exceedance numbers and percentage rates under high and low flow conditions at sites L-48 and L-48A in South Big Horn Creek

		CAL Exceedance		AAL Exceedance		HH Exceedance	
Flow Conditions	Sample Size	Number	%	Number	%	Number	%
High Flow	41	20	49	20	49	1	2
Low Flow	50	9	18	9	18	11	22
All Flows	91	29	32	29	32	12	13

No HH or aquatic life criteria for zinc are exceeded in any of 35 samples collected from site L-21. Both the aquatic life and HH criteria are exceeded by more than 10 percent of low flow samples and more than 10 percent of high flow samples exceed the aquatic life criteria. These exceedance rates, plus the HH exceedances, require a zinc TMDL in South Big Horn Creek.

F 2.3.3 South Big Horn Creek Supplemental Indicators

There are no marcroinvertebrate metrics (MMI/RIVPACS) or sediment chemistry data available for South Big Horn Creek. **Figure F-5** shows the data distributions for sulfate at sites L-21, L-48, and L-48A.

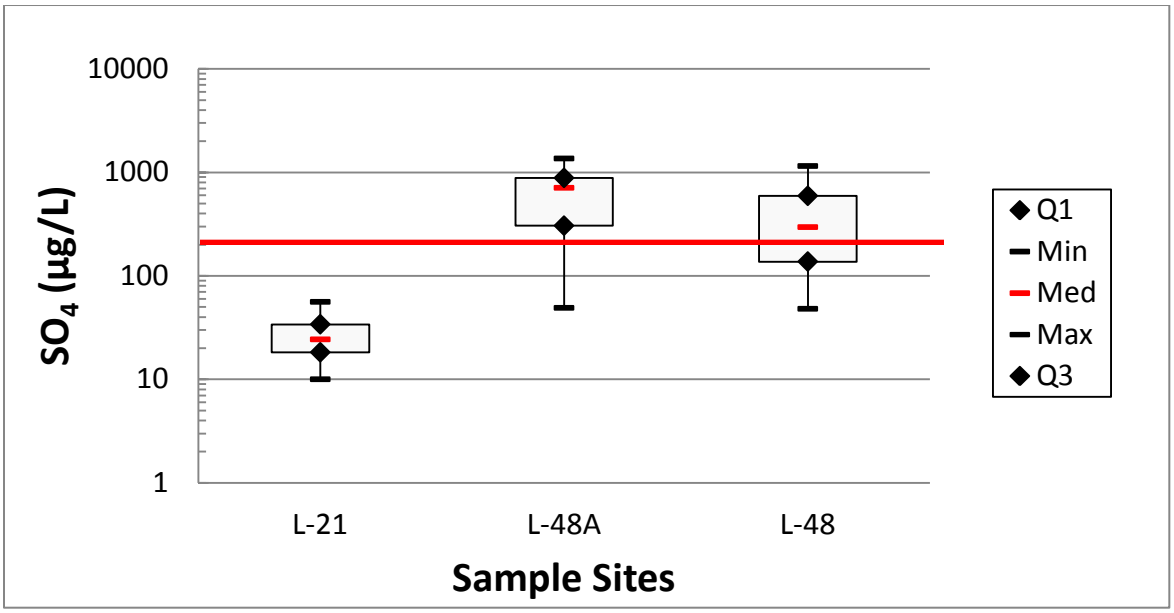

Figure F-5. Boxplot graph of sulfate data distributions for sites L-21 (background), L-48 and L-48A compared to the 200 µg/L indicator value.

The graph shows the continued effect of sulfide oxidation on South Big Horn Creek surface water below the confluence with Swift Gulch Creek.

F 2.3.4 South Big Horn Creek TMDL Development Conclusions

The small dataset (n=6) from current condition sites, high MDLs, 25 percent CAL exceedance rate, and previous aluminum listing support an aluminum TMDL in South Big Horn Creek. Similarly, the high rates of CAL and HH exceedance for cadmium, iron, nickel, and zinc indicate that TMDLs are needed for these metals. Although only one HH exceedance has occurred for arsenic, it was detected within the most recent 10-year period of record for a stream with a current arsenic listing. These factors combine to also require an arsenic TMDL in South Big Horn Creek.

F 2.4 KING CREEK (MT40I001_030)

King Creek is listed in the 2010 Integrated Report as being impaired by selenium. The segment is classified as B-1 and extends for 0.9 mile from its headwaters near the Landusky Mine pit area to the Fort Belknap Reservation boundary (**Figure F-6**). In addition to the listing for selenium, a review of the King Creek water quality record identified elevated concentrations of arsenic and cadmium. Current water quality conditions are represented by the records for sites 503, L-5, and L-39.

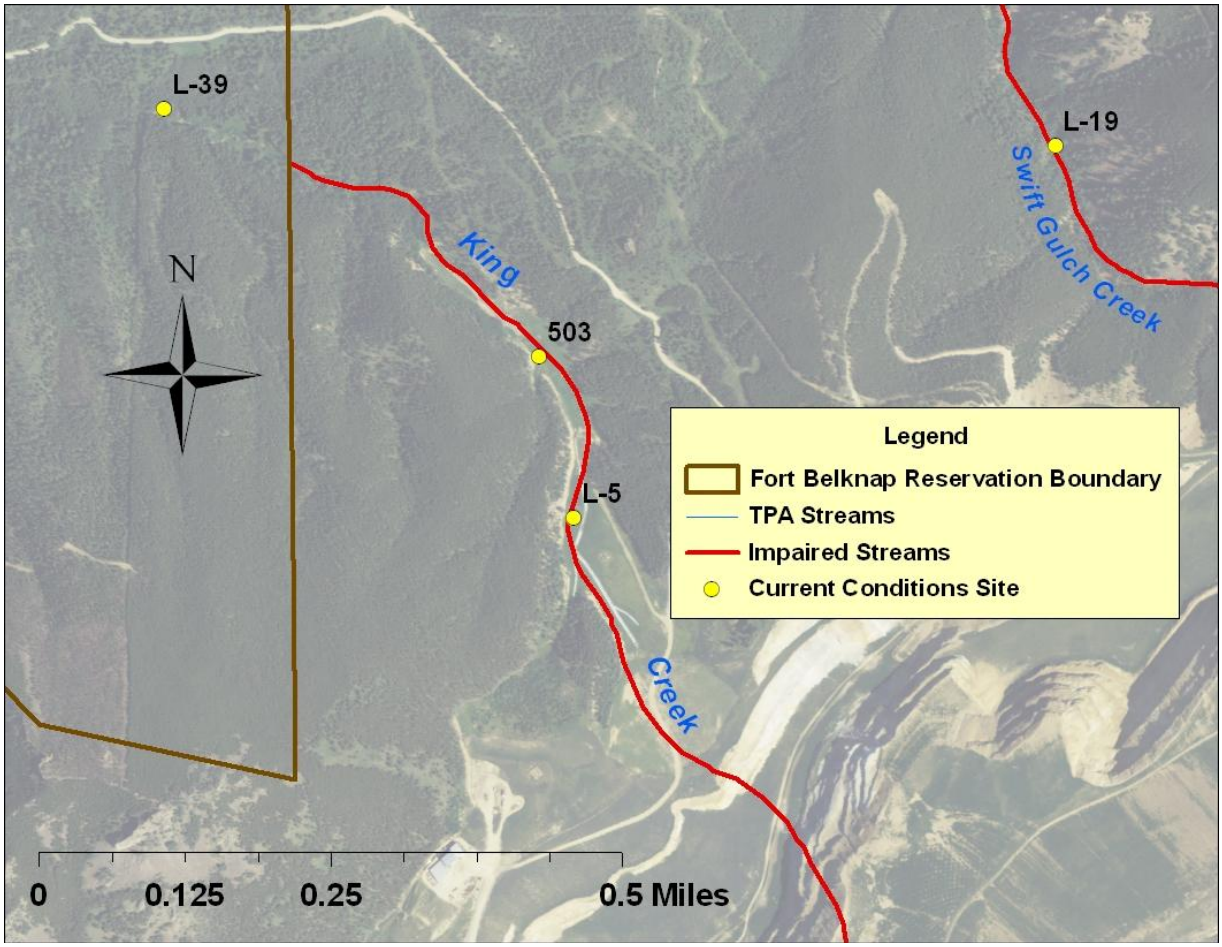

Figure F-6. King Creek and current condition sites extending from the August-Surprise-Queen Rose pit complex at the Landusky Mine to the Fort Belknap Reservation boundary

F 2.4.1 King Creek Sources

During the 1930s the August Mine and cyanide mill in upper King Creek deposited waste rock and tailings downstream. Between 1979 and 1984, ZMI operations created the August #2 Waste Rock Dump in the headwaters of King Creek. The dump was constructed in eastern and western lobes that totaled 1.3 million tons of mostly oxide mineralogy (Spectrum Engineering, Inc., 2006). The west lobe was covered with topsoil and revegetated in 1992. The eastern lobe was completely removed for Landusky pit backfill during 2002 to 2004. The historic August tailings were removed by a joint EPA-Army Corp of Engineers project in 2000. Current sources are stormwater runoff from disturbed areas at the top of the drainage, seepage through regarded and revegetated waste rock, and possibly seepage from the former August pit. Stormwater is retained by two rock check dams and the larger Cumberland Dam constructed about 2,200 feet from the top of the drainage. Groundwater flow is captured in an interception trench and routed to a passive treatment system for nutrient removal. Treated water discharges downstream to the impoundment behind the Cumberland Dam.

Early mining in the drainage precludes locating natural background sites in the King Creek drainage. Records dated from 1978 for sites L-5 and L-6 may reflect water quality prior to placement of the August #2 Waste Rock Dump, but are not likely to reflect natural background water quality because of historic

sources. An ephemeral headwaters reach of King Creek receives snowmelt and precipitation runoff from the undisturbed northeastern flank of Mission Peak. Site L-40, located in a headwater tributary of Montanan Gulch, drains the undisturbed southern slope of Mission Peak. Water quality at site L-40 is assumed as the best approximation of natural background conditions at the base of Mission Peak.

F 2.4.2 King Creek Parameter Departures

Arsenic

There are 99 arsenic results for sites 503, L-5 and L-39 for samples collected from 1982 to 2010. Seventy are since 2000. **Table F-11** summarizes the arsenic exceedance record for the past 10 years. The record contains five HH exceedances that occurred between 2001 and 2008. Three of the five exceedances occurred during high flows in 2001 and 2004. The most recent was 11 µg/L in a 2008 sample from the interception trench discharge at site L-5. Because of the HH exceedances, an arsenic TMDL is required for King Creek.

Table F-11. Arsenic criteria exceedance numbers and percentage rates under high and low flow conditions at sites 503, L-5 and L-39 in King Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	37	0	0	0	0	3	8
Low Flow	33	0	0	0	0	2	6
All Flows	70	0	0	0	0	5	7

Six samples from site L-40 contained less than detectable amounts of arsenic.

Cadmium

There are 70 results for cadmium in King Creek for sites 503, L-5 and L-39. The exceedance record is summarized in **Table F-12**. Nearly half of the cadmium results exceed the CAL criteria. Exceedances are evenly split between high and low flows. The four results exceeding the HH criterion are all from site L-5, the seepage discharge from intercepted stormwater and shallow groundwater near the head of the drainage. The CAL exceedance rates, together with the HH criterion exceedances, require a cadmium TMDL.

Table F-12. Cadmium criteria exceedance numbers and percentage rates under high and low flow conditions at sites 503, L-5 and L-39 in King Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	38	16	42	0	0	2	5
Low Flow	32	16	50	0	0	2	6
All Flows	70	32	46	0	0	4	6

Cadmium concentrations in L-40 samples were less than MDLs.

Selenium

There are 60 post-2000 results for selenium from sites L-5 and L-39. The criteria exceedance record under high and low flows is summarized in **Table F-13**.

Table F-13. Selenium criteria exceedance numbers and percentage rates under high and low flow conditions at sites L-5 and L-39 in King Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	30	19	63	8	27	1	3
Low Flow	30	22	73	17	57	1	3
All Flows	60	41	68	25	42	2	3

The exceedance rates for CAL and AAL criteria are greater than 10 percent and the dataset includes two HH exceedances. Nearly all selenium concentrations in samples from site L-5 exceed the CAL criterion and all AAL and HH exceedances are results from L-5. A selenium TMDL is required to King Creek.

F 2.4.3 King Creek Supplemental Indicators

There are no marcroinvertebrate metrics (MMI/RIVPACS) or sediment chemistry data available for King Creek. **Figure F-7** shows the data distributions for sulfate at sites L-5, 503, and L-39. The graph shows the continued effect of sulfide oxidation in upper King Creek and the decreased concentrations downstream.

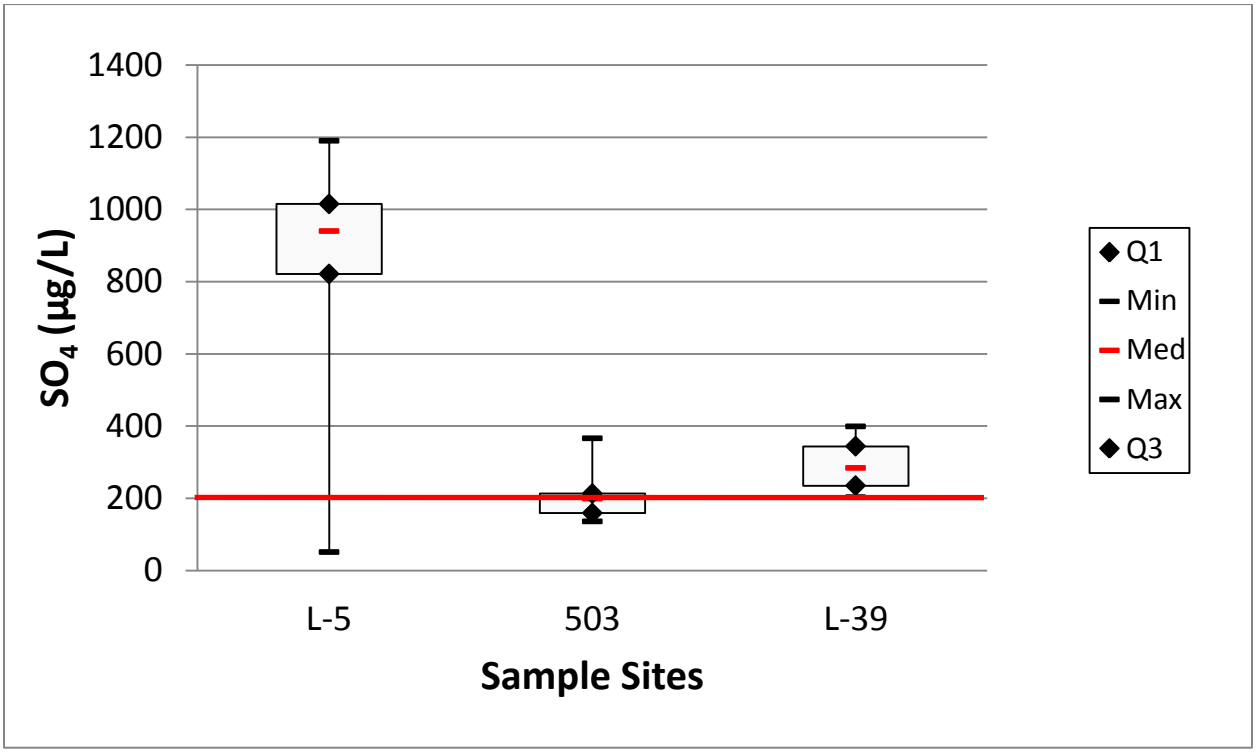

Figure F-7. Boxplot graph of sulfate data distributions at selected monitoring points compared to the 200 µg/L indicator value

F 2.4.4 King Creek TMDL Development Conclusions

Human health criteria exceedances for arsenic, cadmium and selenium, and aquatic life criteria exceedance rates for cadmium and selenium that are greater than 10 percent indicate the need for arsenic, cadmium and selenium TMDLs in King Creek.

F 2.5 LODGE POLE CREEK (MT40I001_050)

Lodge Pole Creek is listed as impaired for cadmium and mercury in the 2010 Integrated Report(Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010). The stream is classified as B-1 and extends north for 4.3 miles from its headwaters along the northern margin of the Zortman Mine to the Fort Belknap Reservation boundary. Current water quality conditions are represented by records from sites Z-7 and Z-29 (**Figure F-8**). Site Z-29 is located on an unnamed eastern headwater tributary of Lodge Pole Creek. Most of the surface and groundwater monitoring stations for Lodge Pole Creek are along this tributary because it occurs in the drainage area disturbed by the northern extent of the Zortman Mine. Natural background conditions are represented by sites Z-28 and Z-30. These sites are located in the upper reaches of the unnamed tributary that are undisturbed except for an access road descending from the Zortman Mine into Beaver Creek. Site Z-27 in **Figure F-8** is located in the headwaters of Beaver Creek.

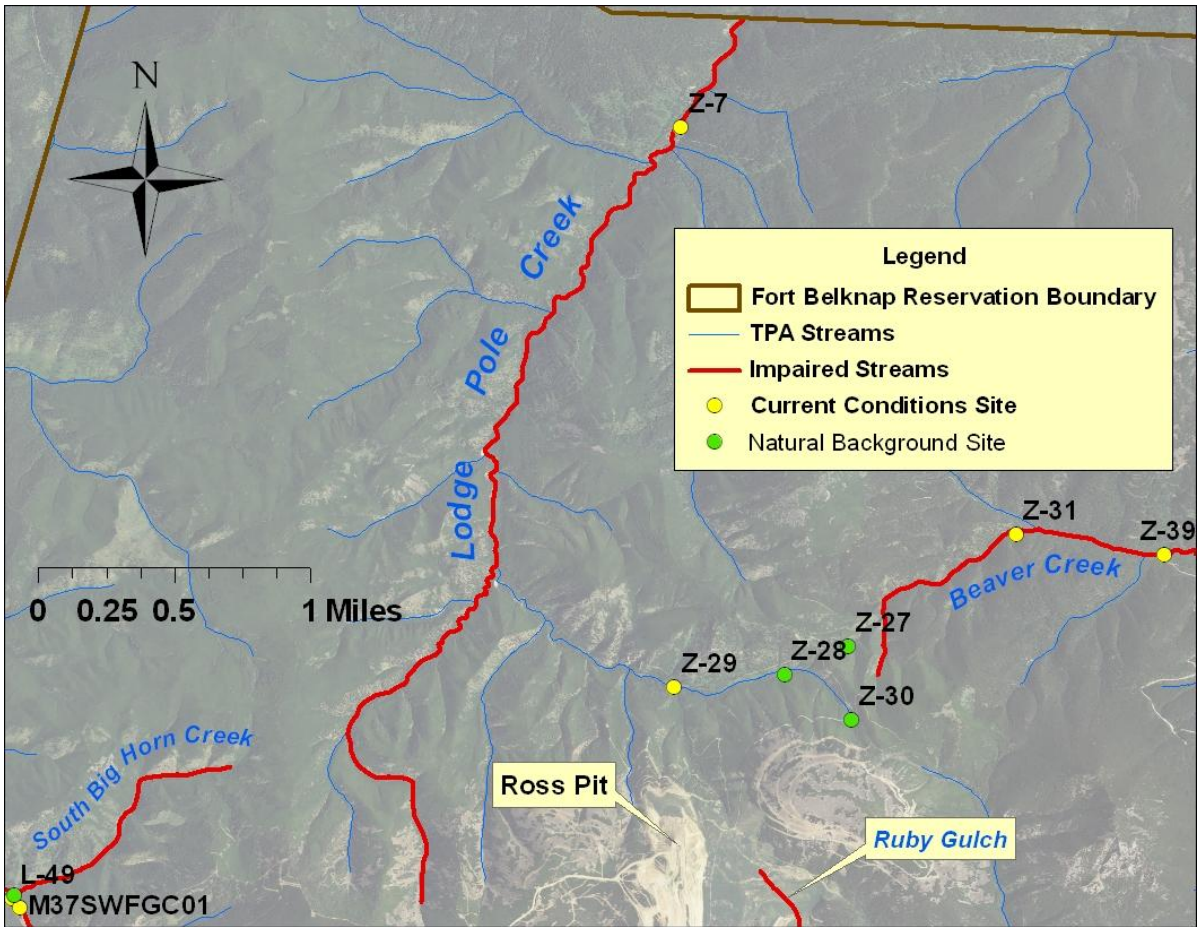

Figure F-8. Lodge Pole Creek extending from the northern edge of the Zortman Mine disturbance to the Fort Belknap Reservation boundary

F 2.5.1 Lodge Pole Creek Sources

The principal mining source of metals loading to Lodge Pole Creek is surface water draining from the Ross Pit area of the Zortman Mine. Site Z-29 is located just below the confluence of Glory Hole Creek and the unnamed eastern tributary of Lodge Pole Creek. The Ross Pit and related roadways and surface

disturbances are within the Glory Hole Creek drainage area. Farther east are disturbances on the north slope of Antoine Butte that may contribute sediment from historic abandoned mines. The Ross Pit is the northern most pit at the Zortman Mine. The pit area was re-graded, treated with lime and cover soil, and revegetated in 2004.

The data record for sites Z-29 and Z-7 includes 108 analytical results dating from 1978 to 1998. The most recent data is for sample collected at site Z-7 in April of 2004. All records for sites Z-28 and Z-30 are dated from 1990-1998.

F 2.5.2 Lodge Pole Creek Parameter Departures

Cadmium

The 63 cadmium results available from sites Z-29 and Z-7 include four positive detections and 59 results below the MDLs of 10, 1 and 0.1 µg/L. The cadmium criteria exceedance record is summarized in **Table F-14**.

Table F-14. Cadmium criteria exceedance numbers and percentage rates under high and low flow conditions at sites Z-7 and Z-29 in Lodge Pole Creek

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	15/31/31	1	7	0	0	0	0
Low Flow	16/32/32	2	12.5	0	0	0	0
All Flows	31/63/63	3	10	0	0	0	0

Sites representing natural background conditions (Z-28 and Z-30) have 16 cadmium results with MDLs low enough to assess CAL compliance. Among these 16, there is one CAL exceedance and one AAL exceedance for data collected sporadically between 1991 and 1998, under mostly high flow conditions. There were no additional AAL or HH exceedances among the remaining 18 results reported with a 1 µg/L MDL. Natural background conditions for cadmium are not markedly different from those downstream of potential sources at sites L-29 and L-7 that cumulatively have three exceedances. Despite the low number of cadmium exceedances, the previous cadmium listing and the uncertainty in the aging dataset justify a cadmium TMDL for Lodge Pole Creek.

Mercury

The mercury listing for Lodge Pole Creek resulted from an extrapolation of HH exceedances measured at USGS gaging station 06154430 at the town of Lodge Pole, located five miles north (downstream) of the Fort Belknap boundary and outside of the planning area. There are 44 results for mercury from inside the planning area at sites Z-29 and Z-7. They are for samples collected from 1990 through 1996. All 44 results at these two sites are less than the reported MDLs. However, all MDLs exceed the HH and CAL criteria. Lower detection limits are required to assess use support for drinking water and aquatic life.

One of two samples collected at site Z-30 on May 15, 1991 contain detectable mercury (3 µg/L); the second sample contained less than 0.2 µg/L. Also on may 15, 1991, there was a positive mercury detection (0.2 µg/L) at site Z-28, located 300 feet downstream of Z-30. These two mercury detections occurred among a total of 24 samples collected from the two headwater sites from 1990 through 1996. There are no documented mining sources of mercury at either site, but historic use of mercury in placer mining cannot be ruled out. The previous mercury listing and uncertainty with the aging dataset justify a mercury TMDL for Lodge Pole Creek.

F 2.5.3 Lodge Pole Creek Supplemental Indicators

There are no marcroinvertebrate metrics (MMI/RIVPACS) or sediment chemistry data available for Lodge Pole Creek. The 83 sulfate results for sites Z-29 and Z-7 range from 8 to 45 mg/L and average 24 mg/L **(Figure F-9)**. The sulfate record does not indicate an influence of ARD on water quality. A similar sulfate record for sites Z-28 and Z-30 contains 36 results ranging from 4 to 53 mg/L, with an average of 13 mg/L. All sulfate concentrations are well below the indicator value of 200 mg/L.

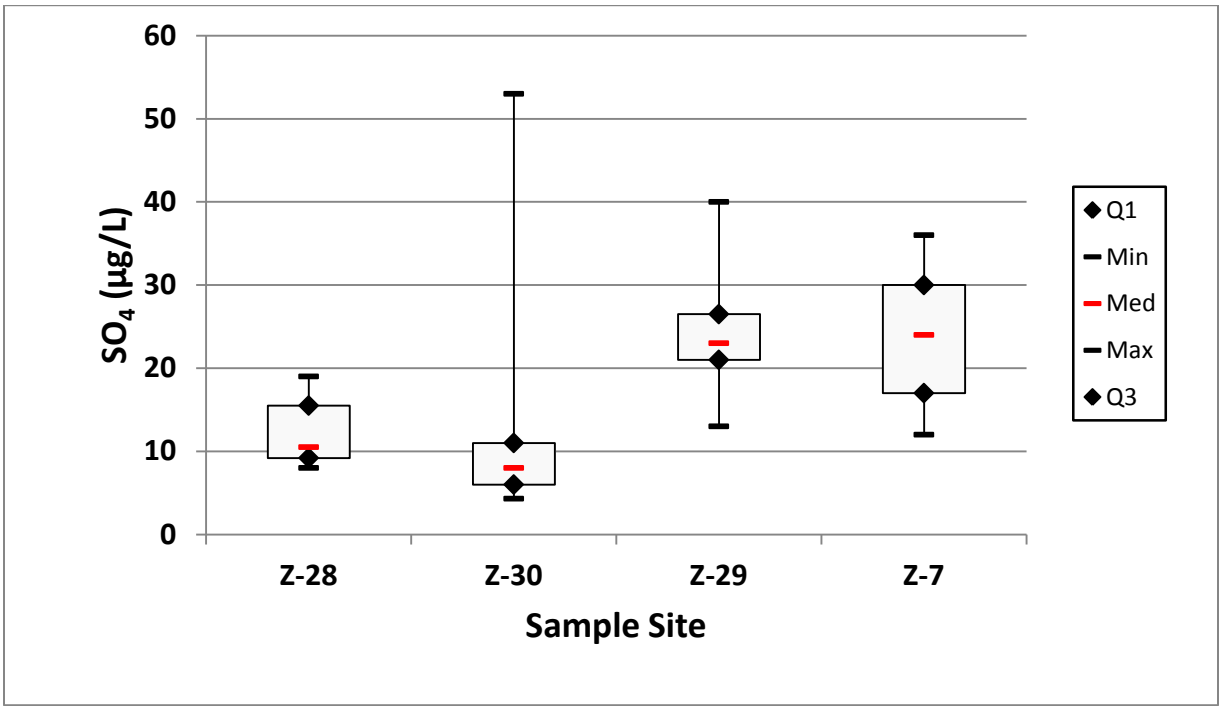

Figure F-9. Boxplot graph of sulfate data distributions at selected natural background sites (Z-28 & Z-30) and current condition sites (Z-29 & Z-7) on Lodge Pole Creek.

F 2.5.4 Lodge Pole Creek TMDL Development Conclusions

Despite the low overall CAL exceedance percentage and low sulfate levels, the current listings for cadmium and mercury, combined with the lack of recent data, support cadmium and mercury TMDLs for Lodge Pole Creek. The assumed valid extrapolation of mercury concentrations at USGS station 06154430 to upstream segments within the planning area, and high MDLs also combine to suggest the need for a mercury TMDL.

F 2.6 Mill Gulch (MT40E002_100)

Mill Gulch was listed as impaired by copper, mercury, lead, selenium, and pH in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010). Despite the C-3 use classification, drinking water use support is assessed in Mill Gulch because of established drinking water use downstream in the town of Landusky. Prior to ZMI mining operations, Mill Gulch extended for 1.7 miles from the crest of the Little Rockies, southward to its confluence with Rock Creek. The upper mile of the drainage is now occupied by the 1987 leach pad, the leach pad dike, and the 56-acre Mill Gulch Waste Rock Dump. The stream channel now extends from the toe of the waste rock

dump near site L-36, to Rock Creek (**Figure F-10**). Current water quality conditions are represented by the records for sites L-36, 506, L-22, and L-7.

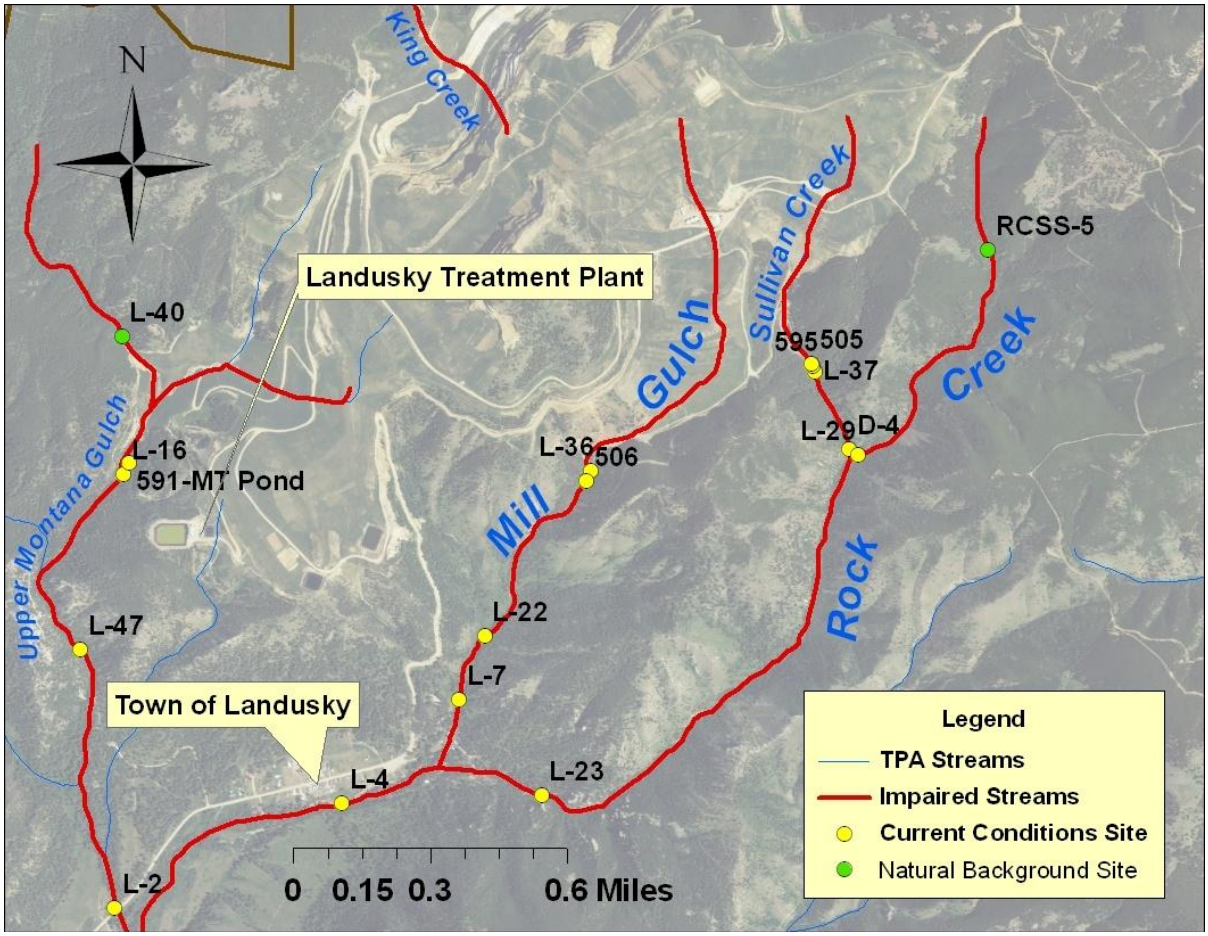

Figure F-10. Mill Gulch extending from the Landusky pit area, south, to its confluence with Rock Creek and existing condition sites L-36, 506, L-22, and L-7

F 2.6.1 Mill Gulch Sources

The main sources of metals loading to Mill Gulch are stormwater and subsurface drainage from the 1987 leach pad, the pad dike, and the Mill Gulch Waste Rock Dump. The dump contains 56 million tons of material placed from 1989 through 1992. Approximately 20 percent of its volume is thought to be sulfide waste rock (Spectrum Engineering, Inc., 2006). The Mill Gulch capture system was installed at the toe of the waste rock dump in September of 1997. Water is piped from the capture system to the Landusky wastewater treatment plant.

The entire Mill Gulch data set includes 279 records for sites, L-36, 506, and L-22 for samples collected between 1979 and 2010, and 66 records for site L-7 from 1979 through 1998. The Mill Creek departure analysis is based on more recent data that includes 55 records since 2000 for sites 506 and L-22, 8 records for site L-36 from 2002 through 2009, and 44 records from the most recent 10 years (1988-1998) for site L-7.

Samples from site L-36 are Mill Gulch capture system bypass discharges that become surface water in upper Mill Gulch. Samples from site 506 consist of stormwater in the Mill Creek channel below the

capture system. Site L-22 is a developed spring in the Mill Creek channel about 750 meters below the capture system. Samples from site L-7 are Mill Creek surface water about 250 meters below L-22.

The degree of mining disturbance in Mill Gulch prevents locating sites that represent natural background conditions. Conceivable natural background sites in this part of the Landusky Mine include site L-40 in an undisturbed tributary of Montana Gulch and site RCSS-5 located to the east in the upper reaches of Rock Creek.

F 2.6.2 Mill Gulch Parameter Departures

Copper

There are 83 results for copper in the existing condition dataset. Fifty-five of 83 have been from sites L-36, 506, and L-22 during the past 10 years. There are 24 copper results from site L-7 dated between 1990 and 1997. The departure analysis includes all 24 results for site L-7, plus the 55 from the other three sites that were obtained during the last 10 years. The criteria exceedance numbers and percentage rates are summarized in **Table F-15**.

Table F-15. Copper criteria exceedance numbers and percentage rates under high and low flow conditions at sites Z-36, 506, L-22 and L-7 in Mill Gulch

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	41	2	5	2	5	2	5
Low Flow	42	6	15	6	15	0	0
All Flows	83	8	10	8	10	2	3

All exceedances in **Table F-15** occurred in samples from site L-36, the bypass of the seepage collection system in Mill Gulch. The eight AAL exceedances were more than double the AAL criteria. There were two HH exceedances. Dilution from groundwater or tributary flows reduces Mill Creek copper levels below all target criteria downstream of site L-36.

There are 12 copper results among the sites representing natural background conditions. Six of these exceed both the CAL and AAL criteria during high flows. No criteria were exceeded under low flow conditions and no samples exceeded the HH criteria. The results suggest that there is potential for background high flow copper concentrations to exceed the aquatic life criteria.

The human health exceedances and AAL exceedances at twice the AAL criteria values require a TMDL for copper in Mill Gulch.

Lead

There are 65 results for lead among the four current conditions sites in Mill Gulch. These include 41 results from sites L-36, 506, and L-22 that have been obtained within the last 10 years, plus all 24 results from site L-7. There are no CAL, AAL, or HH criteria exceedances in this dataset. All 12 lead results for the four natural background sites are less than the reported MDLs, although several MDLs exceed the CAL and HH criteria for lead. The samples are dated 1994 through 1997.

Since lead targets are not exceeded, a lead TMDL is not developed for Mill Gulch.

Mercury

The Mill Gulch dataset contains 46 results for mercury from sites L-22 and L-7. The data was collected from 1990 through 2006. All results are less than the reported MDLs. However, the MDLs (1, 0.2, and 0.6 µg/L), all exceed the 0.05 µg/L HH criterion for mercury. Because of the previous mercury listing and the uncertainty related to high MDLs, a TMDL is developed for mercury in Mill Gulch.

Selenium

There are 48 selenium results available for the four existing condition sites in Mill Gulch. Twenty-seven are for samples collected within the last 10 years from sites L-36, 506, and L-22. Among these 27, the 20 that have MDLs low enough to assess support for aquatic life are used in the departure analysis. **Table F-16** contains the selenium criteria exceedance summary for the existing condition sites in Mill Gulch.

Table F-16. Selenium criteria exceedance numbers and percentage rates under high and low flow conditions at sites, L-36, 506, and L-7 in Mill Gulch

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	9	2	22	2	22	2	22
Low Flow	11	6	55	3	27	0	0
All Flows	20	8	40	5	25	2	10

Both CAL and AAL exceedance rates are greater than 10 percent, requiring a selenium TMDL for Mill Gulch.

There are 14 selenium results available for the four natural background sites. One result in 14 exceeds the CAL criterion.

F 2.6.3 Mill Gulch Supplemental Indicators

There are no marcroinvertebrate metrics (MMI/RIVPACS) or sediment chemistry data available for Mill Gulch. There are 56 sulfate results for sites L-36, 506, and L-22 that have been obtained within the last 10 years. Half of these (28) have exceeded the indicator value of 200 mg/L. Among the four natural background sites there are 14 sulfate results; all are less than 200 mg/L, and have an average of 25 mg/L. The sulfate data distributions for background and current condition sites are illustrated in **Figure 9-11**. The figure shows the influence of capture system overflow at site L-36 on water quality throughout the segment. Water quality at site L-7 may be affected by metals sources related to the lower level leach pads and dikes at the Landusky Mine.

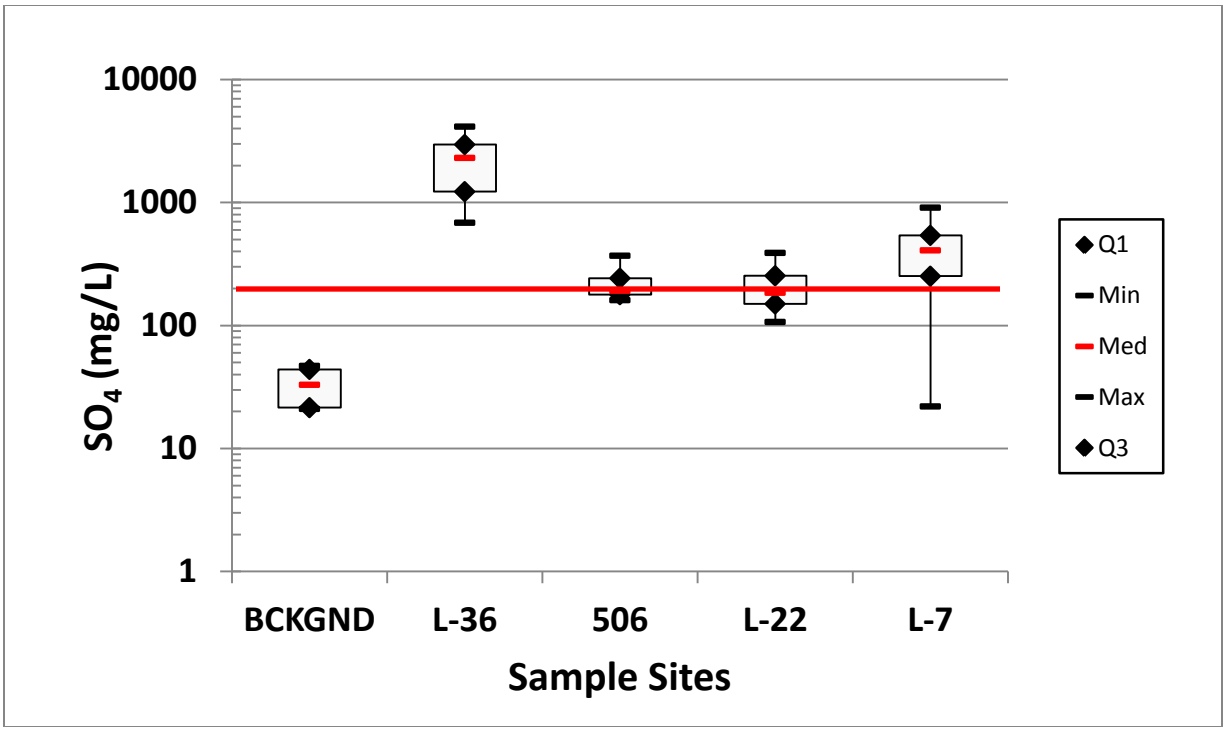

Figure 9-11. Boxplot graph of sulfate data distributions at selected natural background sites (L-40 & RCSS-5) and four current condition sites on Mill Gulch compared to the 200 mg/L indicator value.

F 2.6.4 Mill Gulch TMDL Development Conclusions

The exceedance rates for copper CAL and AAL criteria both slightly exceed 10 percent. The magnitudes of all eight AAL exceedances for copper are more than twice the criteria. The copper dataset for Mill Gulch includes two HH exceedances. The portion of the lead dataset with useful MDLs contains no exceedances. Although the mercury dataset contains recent results, the high MDLs do not allow comparison with the HH criterion. The exceedance rates for CAL and AAL criteria for selenium are greater than 10 percent, include AAL exceedances that are more than twice the criterion, and include HH exceedances. The sulfate data for Mill Gulch indicates continuing effects of ARD on surface water quality compared to background conditions. TMDLs will be developed for copper, mercury, and selenium in Mill Gulch. The lead dataset indicates that criteria are currently being met. Thus, a lead TMDL is not required. It is assumed that the pH impairment will be addressed by the TMDL for copper.

F 2.7 Montana Gulch (MT40E002_010)

Montana Gulch is a perennial stream draining the western third of the Landusky Mine. It is classified as C-3. Although surface water quality in this category is naturally marginal for drinking water, drinking water is considered a designated use and the target departure analysis is based on comparisons to the HH criteria. The stream is listed as impaired by arsenic, cadmium, copper, and pH in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010). A review of water quality data for the past 10 years of record recommended additional impairment listings for aluminum, cyanide, nickel, selenium, and zinc. The stream extends for two miles from the August-Surprise-Queen Rose pit complex at the Landusky Mine to its confluence with Rock Creek (**Figure F-12**).

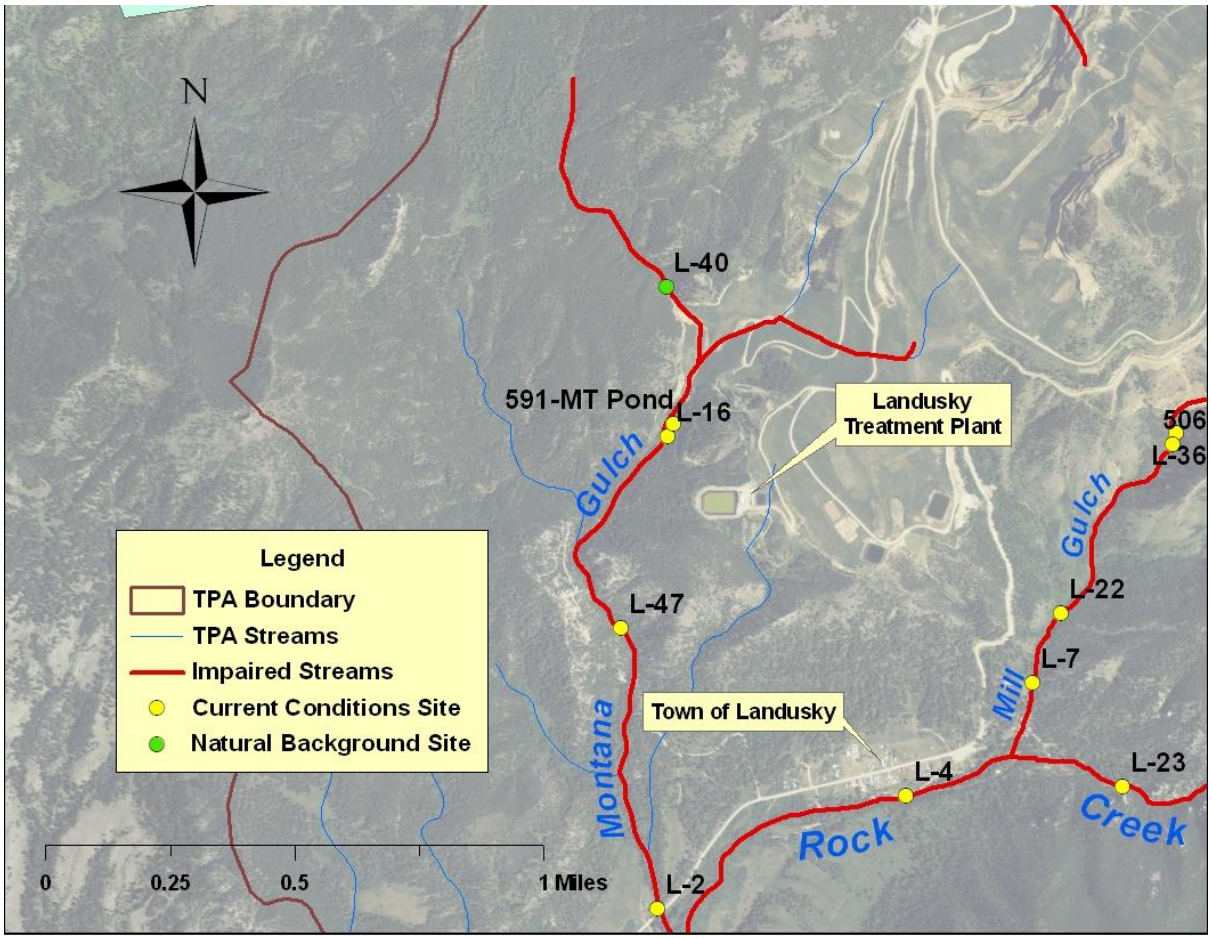

Figure F-12. Montana Gulch, natural background site L-40 and existing condition sites 591, L-16, L-47, and L-2

Current water quality conditions in Montana Gulch are represented by post-2000 records for sites 591, L-16, L-47, and L-2. Natural background conditions are represented by data for site L-40, a surface water monitoring point in an undisturbed western headwater tributary.

F 2.7.1 Montana Gulch Sources

The upstream-most metals loading source is the Montana Gulch Waste Rock Dump. Constructed between 1980 and 1988 in the central headwater tributary of Montana Gulch, this feature covers 29 acres and contains 8.5 million tons of unsorted oxide and sulfide materials (Spectrum Engineering, Inc., 2006). The dump covers the drain tunnel for the former August Mine, located near the divide between Montana Gulch and King Creek. The face of the dump received a layer of coversoil and was revegetated in 1989. The top of the dump was reclaimed in 2005. The upper Montana Gulch seepage capture system is located at the base of the dump.

The L85/86 leach pad, containing 5.3 million tons of mostly oxide ore, was constructed in Montana Gulch below the waste rock dump. The entire leach pad, its supporting dike and fill, and a lower seepage capture system were removed from Montana Gulch from 2003 to 2005. The eastern tributary of upper Montana Gulch contains the drain capture portal for the historic Gold Bug Mine and artesian well WS-3 that controls the groundwater levels in the upper gulch and Landusky pit area. Montana Gulch also contains portions of leach pads and supporting dikes dating from 1980-1984. The Frog Pond Capture

System is located in an ephemeral Montana Gulch tributary to the south of the Landusky wastewater treatment plant. The capture system flow is routed to the Landusky plant. Flow in the tributary below the capture system enters Montana Gulch upstream of monitoring site L-2.

Wastewater from both the Landusky wastewater treatment plant and the Landusky biological treatment plant is discharged to a 0.7-acre lined pond constructed in the bottom of Montana Gulch below the confluence of the three headwater tributaries. The Landusky treatment plant receives effluent from the following sources:

- The Gold Bug Mine portal
- Well WS-3
- Upper Montana Gulch capture system
- Mill Gulch capture system
- Sullivan Creek capture system
- The Frog Pond capture system
- The biological treatment plant.

The plant operates around the clock, discharging about 430 gpm (0.96 cfs). The perennial discharge from the Montana Gulch pond (site 591) enters Montana Gulch at about 530 gpm (1.2 cfs).

F 2.7.2 Montana Gulch Parameter Departures

Aluminum

The dissolved aluminum dataset contains four low flow results from samples collected during August through October of 2009. One sample, containing 7450 µg/L, is more than twice the AAL criterion of 750 µg/L. A TMDL is required for aluminum in Montana Gulch.

Arsenic

The arsenic dataset from the four existing condition sites contains 186 arsenic results. Although all results are less than either the CAL criterion (150 µg/L), or the AAL criterion (340 µg/L), 94 arsenic results (51%) exceed the 10 µg/L HH criterion. Thus, an arsenic TMDL is required for Montana Gulch. Arsenic has not been detected at site L-40.

Cadmium

There are 335 cadmium results with corresponding hardness values. All MDLs are sufficiently low to allow comparison of results with both the CAL and AAL criteria. The cadmium exceedance summary is provided in **Table F-17**.

Table F-17. Cadmium aquatic life and human health criteria exceedance numbers and percentage rates under high and low flow conditions at sites, 591, L-16, L-47 and L-2 in Montana Gulch

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	90	71	79	7	8	19	21
Low Flow	245	129	53	22	9	32	13
All Flows	335	200	60	29	9	51	15

The CAL criteria are exceeded in 60 percent, and AAL criteria are exceeded in nine percent of the samples. There are 51 exceedances of the HH criterion (15%). High flow Cd exceedances are more

common than those at low flow. Since the auatic life exceedance rates are greater than 10 percent and the record contains HH exceedances, a cadmium TMDL is required for Montana Gulch.

Copper

There are 335 copper results with corresponding hardness values. Copper MDLs allow comparison with both CAL and AAL criteria. There are no HH exceedances for copper. The aquatic life copper exceedance summary is provided in **Table F-18**.

Table F-18. Copper aquatic life criteria exceedance numbers and percentage rates under high and low flow conditions at sites, 591, L-16, L-47 and L-2 in Montana Gulch

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance	
		Number	%	Number	%
High Flow	91	2	2	0	0
Low Flow	244	2	1	1	0.4
All Flows	335	4	1	1	0.3

Copper exceedances of both CAL and AAL criteria are well below 10 percent under all flow conditions. Therefore, a copper TMDL is not needed for Montana Gulch. Total recoverable concentrations of Cu were not detected at site L-40.

Cyanide (CN)

There are 465 cyanide results in the Montana Gulch dataset for existing condition sites. **Table F-19** contains the cyanide exceedance summary for aquatic life criteria. The HH cyanide criterion of 140 µg/L was exceeded in one low flow sample.

Table F-19. Cyanide aquatic life criteria exceedance numbers and percentage rates under high and low flow conditions at sites, 591, L-16, L-47 and L-2 in Montana Gulch

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance	
		Number	%	Number	%
High Flow	126	6	5	6	5
Low Flow	339	48	14	33	10
All Flows	465	54	16	39	8

The CAL criterion for cyanide was exceeded in 12 percent of samples. Similar to cadmium, cyanide exceedances are concentrated during low flows. Because of the CAL exceedance rate is greater than 10 percent and the record contains a HH exceedance, a TMDL for cyanide is required in Montana Gulch.

Nickel

There are 145 nickel results in the Montana Gulch dataset for existing conditions. **Table F-20** contains the nickel exceedance summary for aquatic life and HH criteria. There are 27 nickel results that exceed the 100 µg/L HH criterion.

Table F-20. Nickel criteria exceedance numbers and percentage rates under high and low flow conditions at sites, 591, L-16, L-47 and L-2 in Montana Gulch.

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	42	5	12	0	0	0	0

Table F-20. Nickel criteria exceedance numbers and percentage rates under high and low flow conditions at sites, 591, L-16, L-47 and L-2 in Montana Gulch.

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
Low Flow	(101/103/103)	16	16	0	0	27	26
All Flows	(143/145/145)	21	15	0	0	27	19

The CAL criteria for nickel were exceeded in 21 of 143 samples (15 percent). The AAL criteria were not exceeded in any sample. Nickel exceedances are concentrated during low flows. There were three nickel HH exceedances at monitoring points downstream of the Montana Gulch pond overflow. With a 15 percent CAL exceedance rate and the HH exceedances, a nickel TMDL is required for Montana Gulch.

Selenium

There are 146 selenium results in the Montana Gulch dataset for existing condition sites. **Table F-21** contains the selenium exceedance summary for aquatic life and HH criteria. Fifteen selenium results exceed the 50 µg/L HH criterion.

Table F-21. Selenium criteria exceedance numbers and percentage rates under high and low flow conditions at sites, 591, L-16, L-47 and L-2 in Montana Gulch.

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	42	29	69	16	38	4	10
Low Flow	104	60	58	29	28	11	11
All Flows	146	89	61	45	31	15	11

The CAL criterion for selenium was exceeded in 89 samples (61%), and the AAL criterion was exceeded in 45 samples (31%). Exceedances were evenly distributed over both flow conditions. The high aquatic life exceedance rates and the HH exceedances require a TMDL for selenium in Montana Gulch.

At background site L40, the CAL criterion was exceeded in one high flow sample, indicating the possibility of elevated natural background selenium under high flows.

Zinc

There are 334 zinc results in the Montana Gulch dataset for existing condition sites. **Table F-22** contains the zinc exceedance summary for aquatic life and HH criteria.

Table F-22. Zinc criteria exceedance numbers and percentage rates under high and low flow conditions at sites, 591, L-16, L-47 and L-2 in Montana Gulch

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	90	6	7	6	7	3	3
Low Flow	244	13	6	13	6	0	0
All Flows	334	19	5	19	5	3	1

The aquatic life criteria for zinc were exceeded in 19 of 334 results (6%). Although overall exceedance rates are below 10 percent, four zinc results for pond overflow samples were more than double the

aquatic life criteria, and three results exceeded the 2,000 µg/L HH criterion. Thus, a zinc TMDL is required for Montana Gulch. There are no zinc exceedances at background site L-40.

F 2.7.3 Montana Gulch Supplemental Indicators

There are no marcroinvertebrate metrics (MMI/RIVPACS) or sediment chemistry data available for Montana Gulch. There are 301 sulfate results among sites 591, L-16, L-47, and L-2. All exceed the 200 mg/L target value. The sulfate data distributions for background (site L-40) and current condition sites are illustrated in **Figure F-13**.

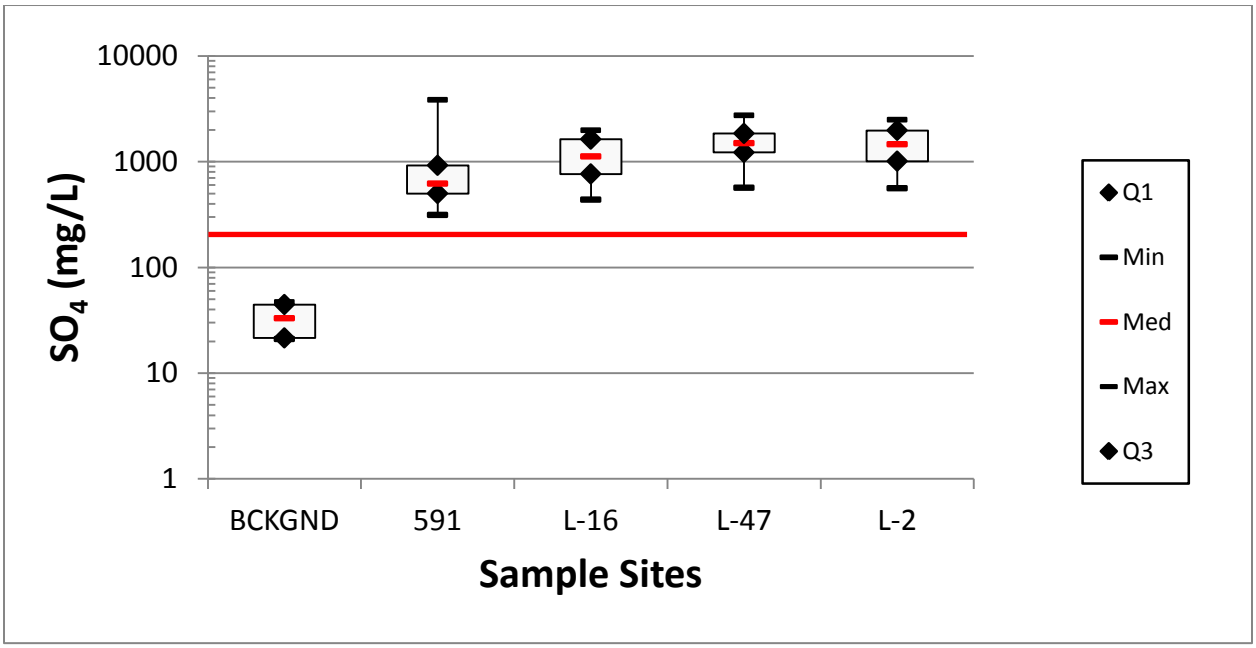

Figure F-13. Boxplot graph of sulfate data distributions at natural background and current condition sites on Montanan Gulch compared to the 200 mg/L indicator value.

The six background sulfate results average 33 mg/L and none exceed the 200 mg/L target value. The increase between background sulfate and current condition sites is the influence of the Landusky WWTP effluent on Montana Gulch surface water downstream of the retention pond discharge.

F 2.7.4 Montana Gulch TMDL Development Conclusions

The existing condition dataset supports TMDL development for aluminum, arsenic, cadmium, cyanide, nickel, selenium, and zinc. Cadmium, cyanide and nickel concentrations exceed the 10 percent exceedance rate for the CAL criteria. Selenium concentrations were above the 10 percent exceedance rate for both CAL and AAL criteria. Several zinc results were more than twice the aquatic life criteria. The HH criteria were exceeded for arsenic, cadmium, cyanide, nickel, selenium and zinc. Cadmium will be used as a surrogate parameter to address the pH impairment listing.

Copper exceedance rates are well under 10 percent for both the CAL and AAL criteria and there were no HH exceedances. The data do not support TMDL development for copper in Montana Gulch.

F 2.8 ROCK CREEK (MT40E002_090)

Rock Creek and its three tributaries of Montana Gulch, Mill Gulch, and Sullivan Creek drain nearly the entire Landusky Mine. **Figure F-14** shows the extent of impaired waters at the Landusky mine and the locations of current condition and background monitoring sites. Rock Creek is an intermittent stream as it flows into the town of Landusky. It is classified as C-3. The HH criteria are considered in assessing Rock Creek metals impairments and the need for TMDLs. Several Landusky wells supply drinking water to residents.

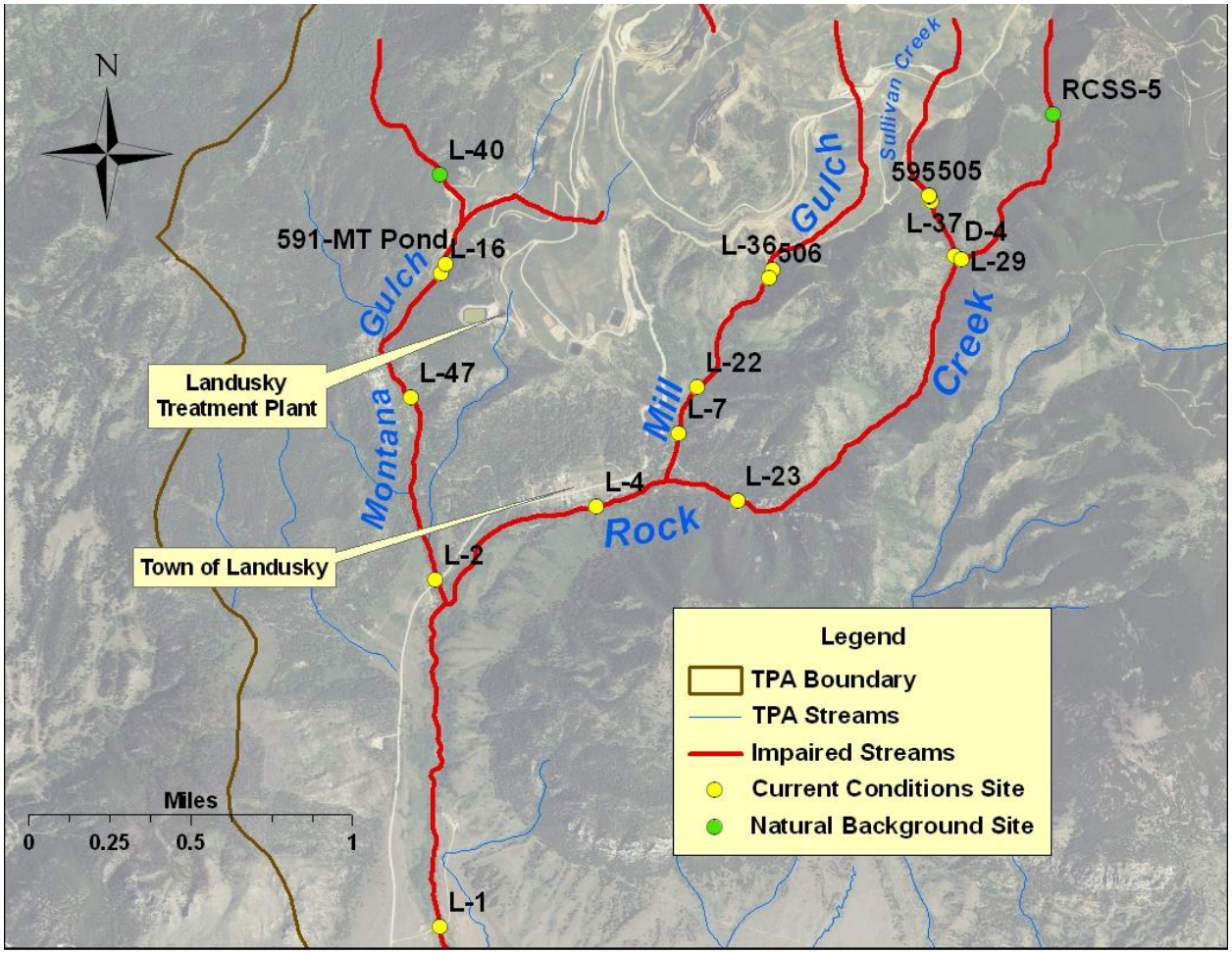

Figure F-14. Extent of Rock Creek, impaired tributaries (left to right) Montana Gulch, Mill Gulch, and Sullivan Creek, and selected water quality monitoring sites

Rock Creek is listed in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) as impaired by cadmium, copper, lead, mercury, selenium, zinc, and pH. Water quality data for sites L-29, L-23, L4, and L-1 is assumed to represent existing conditions. The dataset contains 168 records dating from 1977 to 2004. The size of the dataset for any single parameter is variable. Data collected during the ten most recent years of record is used in the analysis when available.

Site RCSS-5, located in the Rock Creek headwaters, and sites Z-60, Z-61, and Z-62, in the upper reaches of Alder Gulch (**Figure F-1**), are assumed to represent natural background conditions in Rock Creek.

F 2.8.1 Rock Creek Sources

Metals loading sources of to Rock Creek include those described above for Mill Gulch and Montana Gulch. The reach of Rock Creek above the Sullivan Creek confluence may be affected by surface runoff and seepage from the eastern extent of the L91 leach pad, pad underlayment, and dike materials. Downstream of the Sullivan Creek confluence, Rock Creek is influenced by nearly the entire L91 leach pad and dike located at the top of Sullivan Creek. Below Mill Gulch, Rock Creek is affected by Mill Gulch sources, stream-side tailings from historic mills in the town of Landusky, and Montana Gulch sources.

F 2.8.2 Rock Creek Parameter Departures

Cadmium

Among the four existing condition sites there are 71 cadmium results with corresponding hardness values. The cadmium values ranged from 0.1 to 12 µg/L. The cadmium exceedance summary for both aquatic life and HH criteria is provided in **Table F-23**. Cadmium MDLs greater than the CAL criteria reduced the sample size available for CAL target comparisons.

Table F-23. Cadmium criteria exceedance numbers and percentage rates under high and low flow conditions at sites Z-29, L-23, L-4, and L-1 in Rock Creek

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	28/40/40	4	25	1	3	1	3
Low Flow	15/31/31	3	20	0	0	0	0
All Flows	43/71/71	7	16	1	1	1	1

The existing condition Rock Creek cadmium record contains frequent high flow cadmium concentrations exceeding the CAL criteria and a high flow HH exceedance. Among seven cadmium results for the natural background sites, there was one high flow CAL exceedance (0.2 µg/L). The 16 percent CAL exceedance rate and the human health exceedance indicate that a cadmium TMDL is needed for Rock Creek.

Copper

Among the four existing condition sites there are 74 copper results ranging from less than 1 to 58 µg/L. Five of 74 results have MDLs greater than the CAL criteria. The copper exceedance summary for both aquatic life and HH criteria is provided in **Table F-24**.

Table F-24. Copper criteria exceedance numbers and percentage rates under high and low flow conditions at sites Z-29, L-23, L-4, and L-1 in Rock Creek

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	35/33/37	9	26	6	17	0	0
Low Flow	34/37/37	3	9	2	6	0	0
All Flows	69/70/74	12	17	8	12	0	0

The exceedance rates for both aquatic life criteria were greater than 10 percent, indicating the need for a copper TMDL in Rock Creek. Exceedance rates are much higher during high flows. The seven copper results for the background sites are all from high flow samples. Both the CAL and AAL criteria were

exceeded in all seven samples. Therefore, there may be potential for naturally high copper concentrations in Rock Creek during high flows.

Lead

Among the four existing condition sites there are 70 lead results with corresponding hardness values. Fifty-six results have MDLs greater than the CAL criteria. The lead values ranged from less than 2 to 20 µg/L. The lead exceedance summary for aquatic life and HH criteria is provided in **Table F-25**.

Table F-25. Lead criteria exceedance numbers and percentage rates under high and low flow conditions at sites Z-29, L-23, L-4, and L-1 in Rock Creek

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	30/36/36	5	17	0	0	1	3
Low Flow	26/34/34	3	12	0	0	1	4
All Flows	56/70/70	8	14	0	0	2	4

The CAL criteria exceedance rate of 14 percent and two HH criterion exceedances indicate that a lead TMDL is needed in Rock Creek. The seven lead results for the background sites are all less than the MDL of 3 µg/L. The results cannot be used to assess CAL compliance, but no results from background sites exceeded the AAL or HH criteria.

Mercury

There are 44 mercury results for the existing condition sites on Rock Creek. All results are less than reported MDLs that range from 0.2 to 1 µg/L. All MDLs are greater than the 0.05 µg/L HH criterion. Of the 12 results with MDLs less than 1 µg/L, all are less than aquatic life criteria. The seven results from the four background site are all less than 0.6 µg/L. Given the previous mercury listing, extensive mining sources, and uncertainty caused by high MDLs, a mercury TMDL is developed for Rock Creek.

Selenium

There are 72 results for selenium among the current condition sites. Only 14 of these samples contained detectable selenium. Of these 14, one result (9 µg/L) in a sample from site L-1 in August of 2004 exceeded the CAL criterion. Except for the one 2004 sample, the selenium dataset for Rock Creek is pre-2000. The single recent exceedance in an aging dataset raises uncertainty about the current selenium status in a selenium-listed stream. The level of uncertainty justifies a selenium TMDL for Rock Creek. Selenium has not been detected in nine samples collected from the background sites.

Zinc

Among the four existing condition sites there are 77 zinc results with corresponding hardness values and MDLs greater than the CAL criteria. The zinc results are dated during the 1990s and range from less than 10 to 1,040 µg/L. The zinc exceedance summary for aquatic life and HH criteria is provided in **Table F-26**.

Table F-26. Zinc criteria exceedance numbers and percentage rates under high and low flow conditions at sites Z-29, L-23, L-4, and L-1 in Rock Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	43	3	7	3	7	0	0
Low Flow	34	1	0	1	0	0	0

Table F-26. Zinc criteria exceedance numbers and percentage rates under high and low flow conditions at sites Z-29, L-23, L-4, and L-1 in Rock Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
All Flows	77	4	5	4	5	0	0

Although the overall zinc exceedance rates are low, the occurrence of a result (1,040 µg/L) greater than twice the aquatic life criterion (388 µg/L), requires development of a zinc TMDL for Rock Creek. There were no exceedances among the nine zinc results for the background sites.

F 2.8.3 Rock Creek Supplemental Indicators

There are no marcroinvertebrate metrics (MMI/RIVPACS) or sediment chemistry data available for Rock Creek. There are 103 sulfate results among the current condition sites. The data distributions of sulfate from background and current condition monitoring sites are illustrated in **Figure 9-15**. Twenty-eight (27%) of these exceed the proposed 200 µg/L threshold value. Twenty-seven of the 28 samples that exceeded the sulfate threshold were from site L-1, which is located near the sedimentary plains reach of Rock Creek. This location likely has a higher ambient sulfate concentration than surface water in the mountain reaches. Nine sulfate results are available for the background sites. None exceed the 200 µg/L threshold and the average value is 19 µg/L. The significant increase in sulfate between the background sites and site L-29 is likely the effects of the L91 leach pad in Sullivan Creek.

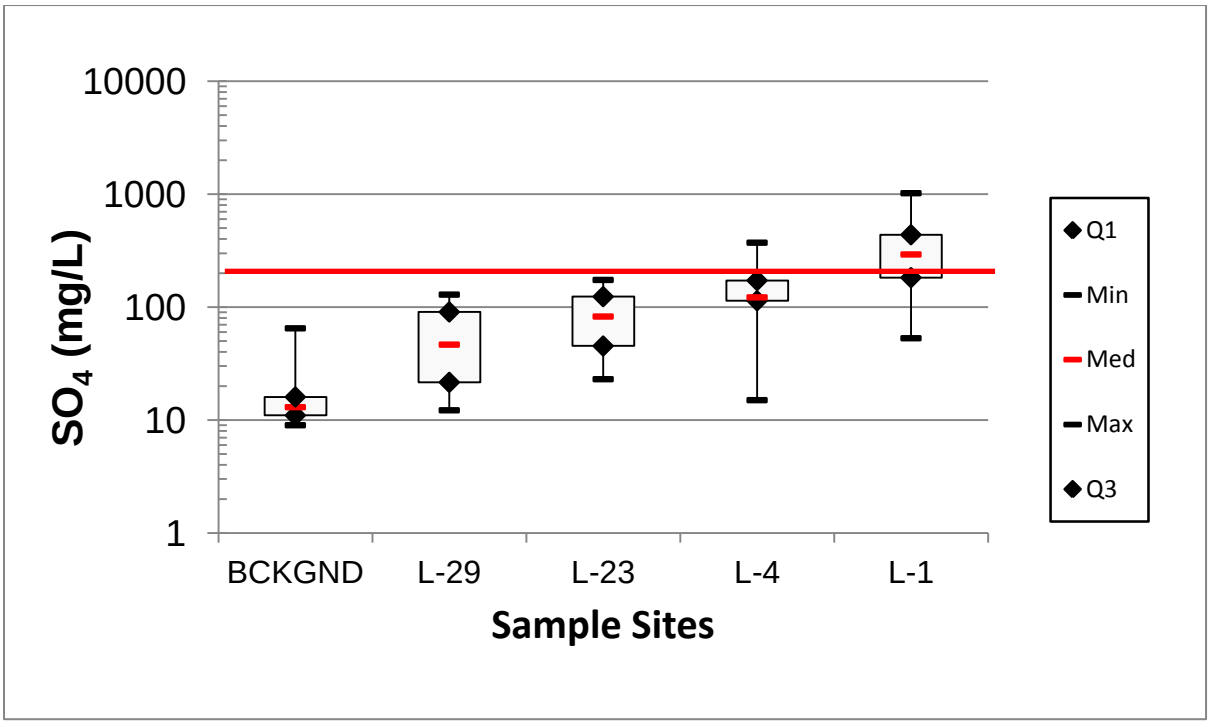

Figure 9-15. Boxplot graph of sulfate data distributions at selected natural background and current condition sites on Rock Creek compared to the 200 mg/L indicator value.

F 2.8.4 Rock Creek TMDL Development Conclusions

The existing condition datasets for cadmium, copper, and lead exceed the 10 percent CAL exceedance threshold, mostly during high flows. The rate of AAL criteria exceedance for copper was also over 10

percent. Human health criteria are exceeded for both cadmium and lead. These conditions support the need for cadmium, copper, and lead TMDLs.

The entire mercury dataset is pre-1998 and has MDLs that are too high to allow a compliance assessment of the HH criterion. A TMDL for mercury will be developed in response to the uncertainty in HH compliance for a stream with a previous mercury listing.

An aging dataset is also an issue for interpreting selenium impairment. The only result available for the past 13 years exceeds the CAL criterion, so a selenium TMDL will be developed to address the listing.

A zinc result of more than twice the aquatic life criteria justifies a zinc TMDL. Since metals impairments are linked to low pH conditions, cadmium will serve as a surrogate parameter to address the pH listing.

F 2.9 RUBY GULCH (MT40E002_070)

Ruby Gulch is listed as impaired in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) for cadmium, chromium, copper, lead, mercury, selenium, zinc, and pH. The segment is classified as C-3 and extends for 2.9 miles from its headwaters to its confluence with Alder Gulch. Prior to ZMI mining operations, Ruby Gulch flowed at its headwaters from several springs discharging from extensive historic underground mine workings. Along its lower reach near the town of Zortman, it flows largely in response to significant precipitation or snowmelt.

Ruby Gulch receives the outfall from the Zortman wastewater treatment plant (site 667) about 200 meters upstream of site Z-15 **(Figure F-1)**. From upstream to downstream, current water quality conditions are represented by the plant discharge and sites Z-15, Z-100, and Z-1B. Background conditions are represented by sites RGSP-1, RGSS-1, Z-9 and Z-52 that are surface water monitoring points in drainages from the undisturbed eastern half of the Ruby Gulch watershed.

F 2.9.1 Ruby Gulch Sources

The principal current source of metals loading to Ruby Gulch is the Zortman wastewater treatment plant. The plant receives effluent from three seepage capture systems; the Carter Gulch capture, the Alder Spur capture and the Ruby capture. The Carter Gulch capture collected seepage from beneath the Alder Gulch Waste Rock Dump until the system was destroyed by a slope failure near the base of the dump in May of 2011. The Alder Spur capture system collects seepage from the Z83 and Z84 leach pads and dikes. The Ruby capture system includes an 8.9 million gallon lined pond constructed in upper Ruby Gulch. The pond collects seepage from upslope springs that were covered by the Z85/Z86 leach pad and dike system. The pond also receives seepage from two underground mine adits located near the southwestern edge of the Z85/Z86 leach pad.

The Zortman treatment plant began operating in June of 1994. For the past five years the annual effluent volume has averaged about 87 million gallons during part-time operations. According to Spectrum Engineering (2006) the plant operates approximately 72 hours per week. The effluent is discharged from outfall 667 into the channel of Ruby Gulch upstream from monitoring site Z-15.

F 2.9.2 Ruby Gulch Parameter Departures

Aluminum

Although not listed in 2010 for aluminum, a review of the metals dataset for Ruby Gulch identified a number of standards exceedances. There are 11 results for aluminum in samples having a pH range of from 6.5 to 9.0. Four of 11 results have MDLs that exceed the CAL criterion. Of the remaining seven results, six (86%) exceed the CAL criterion. Three of 11 samples (27%) exceed the AAL criterion.

Cadmium

There are 422 results for cadmium for the four current condition sites that date from 1990 to 2010. Data from the most recent 10 years for each site brings the total down to 313 results dating from 1995 to 2010. The cadmium exceedance summary for aquatic life criteria is provided for the existing condition sites in **Table F-27**.

Table F-27. Cadmium criteria exceedance numbers and percentage rates under high and low flow conditions at sites 667, Z-15, Z-100 and Z-1B in Ruby Gulch

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	105	90	86	22	21	33	31
Low Flow	208	183	88	58	29	78	38
All Flows	313	273	87	80	26	111	35

There are five cadmium results dating from 1994 to 1997 for the four background sites. Cadmium has not been detected in samples from these sites.

The CAL criteria are exceeded in 87 percent of Ruby Gulch samples and the AAL criteria are exceeded in 26 percent of samples. Three results are more than double the AAL criteria and the HH criterion is exceeded in 35 percent of the samples. The rate of aquatic life and HH criteria exceedances requires a cadmium TMDL in Ruby Gulch. Cadmium will serve as the surrogate parameter for addressing pH conditions in Ruby Gulch.

Chromium (Cr)

The assessment record for Ruby Gulch contains documentation of a single CAL exceedance for chromium in a sample from an upper Ruby Gulch well during a 1994 sampling event. There are 21 surface water chromium results for sites Z-15 and Z-1b that date from 1990 through 1996. There are no chromium criteria exceedances among these samples. The dataset for Ruby Gulch contains no results for chromium during the past 15 years. The assumed validity of the previous chromium listing and age of the existing chromium dataset justify development of a chromium TMDL for Ruby Gulch.

Copper

There are 313 results for copper for the four current condition sites that date from 1995 to 2010. The aquatic life exceedance summary for copper is provided in **Table F-28**. There are no HH exceedances for copper. There are five copper results dating from 1994 to 1997 for the four background sites. Copper has not been detected at these sites.

Table F-28. Copper criteria exceedance numbers and percentage rates under high and low flow conditions at sites 667, Z-15, Z-100 and Z-1B in Ruby Gulch

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance	
		Number	%	Number	%
High Flow	105	14	13	14	13
Low Flow	208	7	3	3	1
All Flows	313	21	7	17	5

Copper aquatic life criteria exceedances rates are less than 10 percent of a large and current dataset. A copper TMDL is not required for Ruby Gulch.

Cyanide

The existing condition sites have 408 cyanide results dating from 1995 to 2011. The record contains no HH exceedances for cyanide. The aquatic life exceedance summary for cyanide is provided in **Table F-29**.

Table F-29. Cyanide criteria exceedance numbers and percentage rates under high and low flow conditions at sites 667, Z-15, Z-100 and Z-1B in Ruby Gulch

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance	
		Number	%	Number	%
High Flow	134	38	28	16	12
Low Flow	274	72	26	3	1
All Flows	408	110	27	19	5

The CAL criterion for cyanide is exceeded in 110 samples (27%) and the AAL criterion was exceeded in 19 samples. Exceedances were evenly divided between high and low flow conditions. Twelve of the 19 AAL exceedances were more than twice the 22 µg/L criterion. All but one of the exceedances occurred in the Zortman wastewater treatment plant outfall. The high CAL exceedance rate and occurrences of values twice the AAL criterion require a cyanide TMDL in Ruby Gulch.

Lead

There are 257 results for lead, dating from 1995 to 2010, at three of the four current condition sites. The exceedance summary is summarized in **Table F-30**. The analysis included seven results for site Z-1B. Five of the seven site Z-1B results exceed both the aquatic life and HH criteria for lead. No lead exceedances occurred at sites 667 and Z-15.

Table F-30. Lead criteria exceedance numbers and percentage rates under high and low flow conditions at sites 667, Z-15, and Z-1B in Ruby Gulch

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%		
High Flow	91	4	4	1	1	4	4
Low Flow	166	1	1	0	0	1	1
All Flows	257	5	2	1	0	5	2

There are five lead results dating from 1994 to 1997 for the four background sites. The MDLs reported with the two samples from 1994 and 1995 exceed the CAL criteria. Lead was not detected in the

remaining three samples. No exceedances of AAL criteria for lead have occurred in data from the past ten years. Although the exceedances occurred in older data, only one sample has been collected during the past 10 years from site Z-1B, where the exceedances are concentrated. The uncertainty regarding the current water quality at site Z-1B, the HH exceedances, and the previous lead listing prompt development of a lead TMDL in Ruby Gulch.

Mercury

Among 47 mercury results for the existing condition sites in Ruby Gulch, there is a single positive detection of 2.0 µg/L in a 2003 sample of the Zortman treatment plant outfall. The result exceeds both the HH and AAL criteria. Mercury was not detected in samples from the background sites. The previous listing, presence of mining sources, and uncertainty associated with the single elevated result in the treatment plant outfall justify a mercury TMDL for Ruby Gulch.

Selenium

There are 177 results for selenium from three of the four the current condition sites. No selenium data are available for site Z-1B. **Table F-31** summarizes the selenium aquatic life exceedance record for Ruby Gulch. The record contains no HH exceedances.

Table F-31. Selenium criteria exceedance numbers and percentage rates under high and low flow conditions at sites 667, Z-15, and Z-100 in Ruby Gulch

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance	
		Number	%	Number	%
High Flow	53	28	53	0	0
Low Flow	124	76	61	0	0
All Flows	177	104	59	0	0

All but two exceedances occurred at site 667, the Zortman wastewater treatment plant discharge. The rate of CAL exceedances is greater than 10 percent under both high and low flow conditions, requiring a selenium TMDL for Ruby Gulch. Selenium criteria are not exceeded in any of the six results from the background condition sites.

Zinc

There are 312 results for zinc among the four current condition sites. The results date from 1995 to 2010. The zinc exceedance summary for Ruby Gulch is provided in **Table F-32**.

Table F-32. Zinc criteria exceedance numbers and percentage rates under high and low flow conditions at sites 667, Z-15, Z-100, and Z-1B in Ruby Gulch

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance	
		Number	%	Number	%
High Flow	105	4	4	4	4
Low Flow	207	2	1	2	1
All Flows	312	6	2	6	2

There are six exceedances among 312 zinc results. Five of these six occurred at site Z-1B in samples dated from 1995 to 1997. All of the AAL exceedances at Z-1B are more than twice the criteria value and include one HH exceedance. Although there are no exceedances among 307 samples collected since 1997, only one sample has been from site Z-1B. The previous listing for Zn in Ruby Gulch, the uncertainy

regarding the current water quality at site Z-1B, and the HH exceedance prompt development of a TMDL in Ruby Gulch. There are no zinc exceedances among five results for the background sites.

F 2.9.3 Ruby Gulch Supplemental Indicators

Although there is no sediment chemistry or macroinvertebrate metric data available for Ruby Gulch, the sulfate data distributions shown in **Figure F-16** illustrate the effects of sulfide oxidation on water quality throughout the segment.

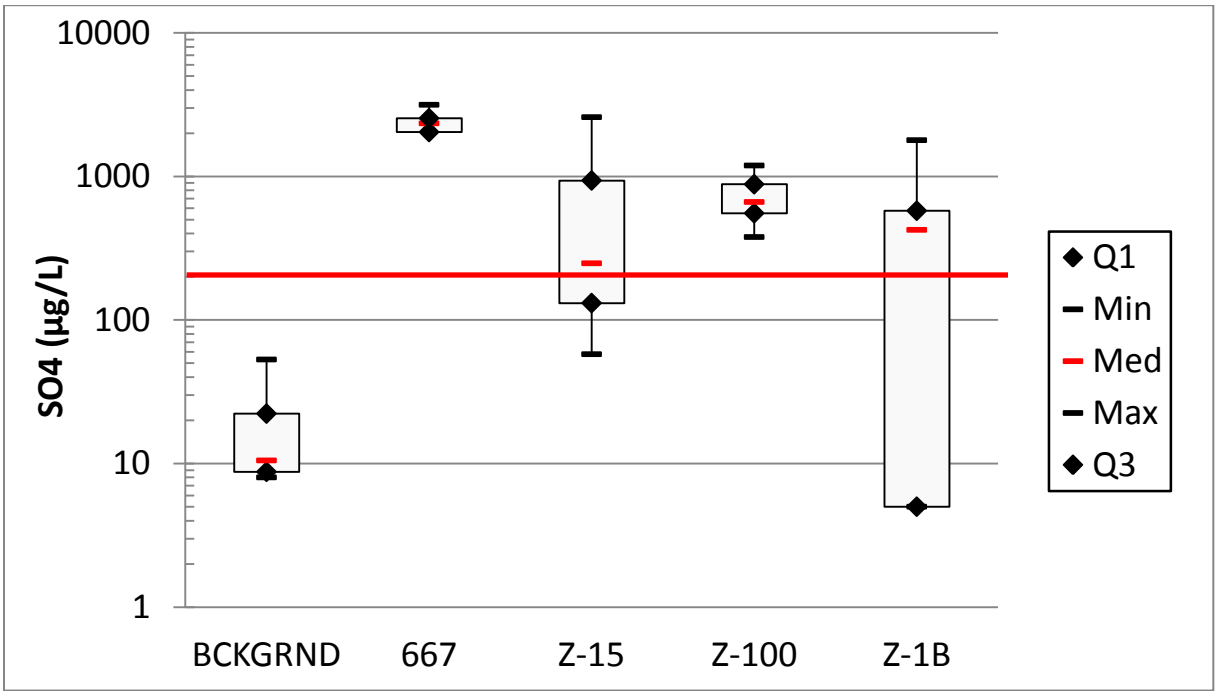

Figure F-16. Boxplot graph of Ruby Gulch sulfate concentration at sites 667, Z-15, Z-100, and Z-1B compared to background levels and the sulfate indicator value of 200 µg/L

F 2.9.4 Ruby Gulch TMDL Development Conclusions

The cadmium exceedance rates for the CAL and AAL criteria are greater than 10 percent. Twenty-nine 29 cadmium results are more than double the AAL criteria and 111 results exceed the HH criteria. The cadmium data indicate the need for a cadmium TMDL. Cadmium will serve as a surrogate parameter to address the Ruby Gulch listing for pH.

The assessment record for chromium in Ruby Gulch indicates that the listing is based on a groundwater sample from the upper portion of the drainage. Exchanges between groundwater and surface water in the Ruby Gulch headwaters are expressed in spring discharges in the upper gulch that were covered by the Z85-86 leach pad and dike. Despite the basis for the listing, it is conceivable that surface water chromium was elevated below the springs prior to construction of the leach pad and dike. The Z-L ACCESS dataset for chromium in Ruby Gulch is dated pre-1997 and contains no chromium exceedances. Assuming that the listing is valid, recent data to document current chromium concentrations are not available and a chromium TMDL is required for Ruby Gulch.

The copper exceedance rates for aquatic life criteria are less than 10 percent. The dataset is a continuous record of surface water copper from 2001 to the present and does not indicate the need for a copper TMDL.

Although the CAL exceedance rate for lead is less than 10 percent, the record for site Z-1B contains several values that are more than twice the AAL criteria for lead and includes HH exceedances. Lacking more recent data for site Z-1B, and considering the previous lead listing for Ruby Gulch, a lead TMDL is needed.

A lengthy record for cyanide in Ruby Gulch includes repeated exceedances of the CAL criterion through 2007. The CAL exceedance rate is greater than 10 percent, indicating the need for a cyanide TMDL.

A positive mercury detection of 2.0 µg/L in a 2003 sample exceeds both HH and aquatic life criteria. The uncertainty introduced by this result and the aging dataset supports a mercury TMDL.

The rate of CAL exceedances (59%) for selenium, mostly in the Zortman wastewater treatment plant outfall, indicated the need for a selenium TMDL.

Although the exceedance rate for aquatic life Zn criteria is less than 10 percent. Results for site Z-1B, located near the town of Zortman, include both aquatic life and HH exceedances, indicating the need for a zinc TMDL.

To summarize, metals TMDLs needed in Ruby Gulch include those for aluminum, cadmium, chromium, lead, mercury, selenium, and zinc. Cadmium will serve as a surrogate parameter for the pH impairment listing. A TMDL will also be developed for the toxin cyanide.

F 2.10 RUBY CREEK (MT40E002_060)

Ruby Creek is listed as impaired in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) for aluminum, cadmium, copper, lead, mercury, selenium, zinc, and pH. The segment is classified as C-3 and extends for 4.6 miles from the confluence of Ruby and Alder gulches to the confluence with CK Creek (**Figure F-17**). Flow in Ruby Creek is largely in response to significant precipitation or snowmelt. Thus, the dataset consists of results for samples collected under high flow conditions. The entire length of Ruby Creek is outside of the igneous core of the Little Rockies mountain range. The Ruby Creek alluvium is underlain by Cretaceous marine shale and sandstone sediments.

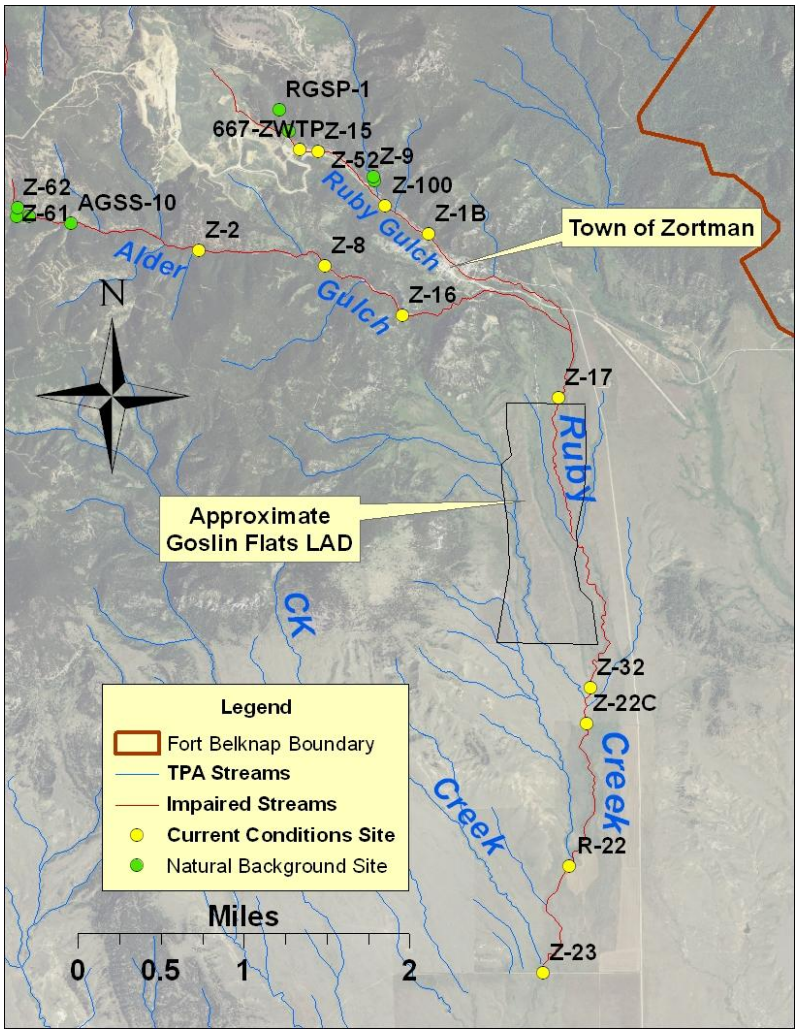

Figure F-17. The Ruby Creek drainage with locations of monitoring sites and Goslin Flats land application disposal (LAD) area.

Current water quality conditions are represented by results from sites Z-17, Z-32, Z-22C, R-22, and Z-23 (**Figure F-17**). The record for site Z-17 consists of three high flow samples collected during the spring of 1990 and 1991. There are 12 records for site Z-32 that include several low flow sampling events. The record for site Z-22C contains a single sampling event on July 13, 2010. Site R-22 has 30 records dating from 2000 through 2010. Like Z-22C, site Z-23 has data for a single sample collected on July 13, 2010. Site Z-23 is on CK Creek 100 meters downstream of its confluence with Ruby Creek. Background conditions are represented by those described above in **Sections F.2.1 and F.2.9** for Alder Gulch and Ruby Gulch.

F 2.10.1 Ruby Creek Sources

The principal metals loading sources are from the Zortman Mine that are described above for Ruby and Alder gulches. Portions of the 410-acre Goslin Flats LAD area occur on both banks of Ruby Creek. Disharges to the LAD area originate as leach pad drainage from both the Zortman or Landusky mines and are piped to the LAD area at an annual rate of about 55 million gallons. Past application has caused elevated cyanide, nitrate, selenium and other metals in shallow groundwater and in channel seeps, springs and ponds In Ruby Creek below the Goslin Gulch confluence.

F 2.10.2 Ruby Creek Parameter Departures

Aluminum

The dissolved aluminum record for Ruby Creek, within the pH range of 6.5 to 9.0, consists of a single sample collected at site Z-32 during high flow (220 gpm) in August of 1997. The result was less than 100 µg/L, an MLD that is greater than the CAL criterion of 87 µg/L. The aluminum listing for Ruby Creek appears to stem from a total recoverable concentration of 64.1 mg/L measured during high flows on May 19, 1991. The dissolved aluminum record from the background condition sites consists of seven high flow results from upper Alder Gulch ranging from 200 to 400 µg/L, all exceeding the CAL criterion. The high flow bias in the background condition results, the previous Al listing, and high MDLs justify an aluminum TMDL for Ruby Creek.

Cadmium

There are 45 results for cadmium in the Ruby Creek data record for current condition sites. The results are for samples from 1990 through 2011. All but two have MDLs less than the CAL criteria. Three values from sites Z-17 and Z-32 are greater than the HH criterion of 5 µg/L and are twice the AAL criterion, indicating the need for a cadmium TMDL in Ruby Creek.

There are 12 cadmium results among the background sites, all are for high flow conditions. Six of 12 have MDLs greater than the CAL criteria. Of the remaining six, three exceed the CAL criterion. There are no AAL or HH exceedances among the results from the background sites. Cadmium serves as a surrogate parameter for addressing the pH impairment in Ruby Creek.

Copper

There are 44 copper results for current condition sites. As with cadmium, several (3) results are twice the AAL criterion for copper, and two results exceed the HH criterion. A copper TMDL is required for Ruby Creek.

There are 12 copper results from the background sites. As with cadmium, all are from high flow samples. Ten results are reported with MDLs greater than the CAL criteria. Among these 10, there are seven CAL exceedances and six AAL exceedances. There are no HH exceedances among the background sites.

Lead

There are nine lead results available for sites Z-17, Z-32, and R-22. Three of nine (30%) exceed the CAL and HH criteria, requiring a lead TMDL for Ruby Creek. There are no exceedances of the AAL criteria for lead.

There are 12 lead results among the background sites. All report less than detectable amounts, but MDLs exceed the CAL criteria for 11 of the 12 results. There are no HH or AAL criteria exceeded in samples from background sites.

Mercury

There are 13 mercury results available for sites Z-17, Z-32, and R-22. Twelve of 13 exceed the both the HH and CAL criteria. Two results exceed the AAL criterion. A mercury TMDL is required for Ruby Creek.

There are 12 mercury results from background sites. Two of the MDLs exceed the CAL criterion and all MDLs exceed the HH criterion.

Selenium

There are 43 selenium results for current condition sites on Ruby Creek, with 30 of these coming from site R-22, a spring discharging into the channel bottom. All results from site R-22 exceed both the CAL and AAL criteria, and the HH criterion for selenium, requiring a selenium TMDL for Ruby Creek. The water quality for site R-22 probably reflects that of the shallow aquifer beneath the LAD area. There are 15 selenium results from background sites. All background results are less than the MDLs and all MDLs are less than the CAL criterion.

Zinc

There are 45 zinc results available for current condition sites. Thirty of these exceed the HH criterion and are more than twice the aquatic life criterion, requiring a zinc TMDL for Ruby Creek. There are 12 zinc results available for the background sites. All are less than the most restrictive target, the aquatic life criteria.

F 2.10.3 Ruby Creek Supplemental Indicators

There is no sediment chemistry or macroinvertibrate metric data available for Ruby Creek. **Figure F-18** illustrates the sulfate data distributions for the combined background sites and three current condition sites. The plots indicate the effects of ARD in Alder and Ruby gulches on the downstream sulfate concentrations in Ruby Creek and shallow groundwater discharging to the Ruby Creek channel at site R-22.

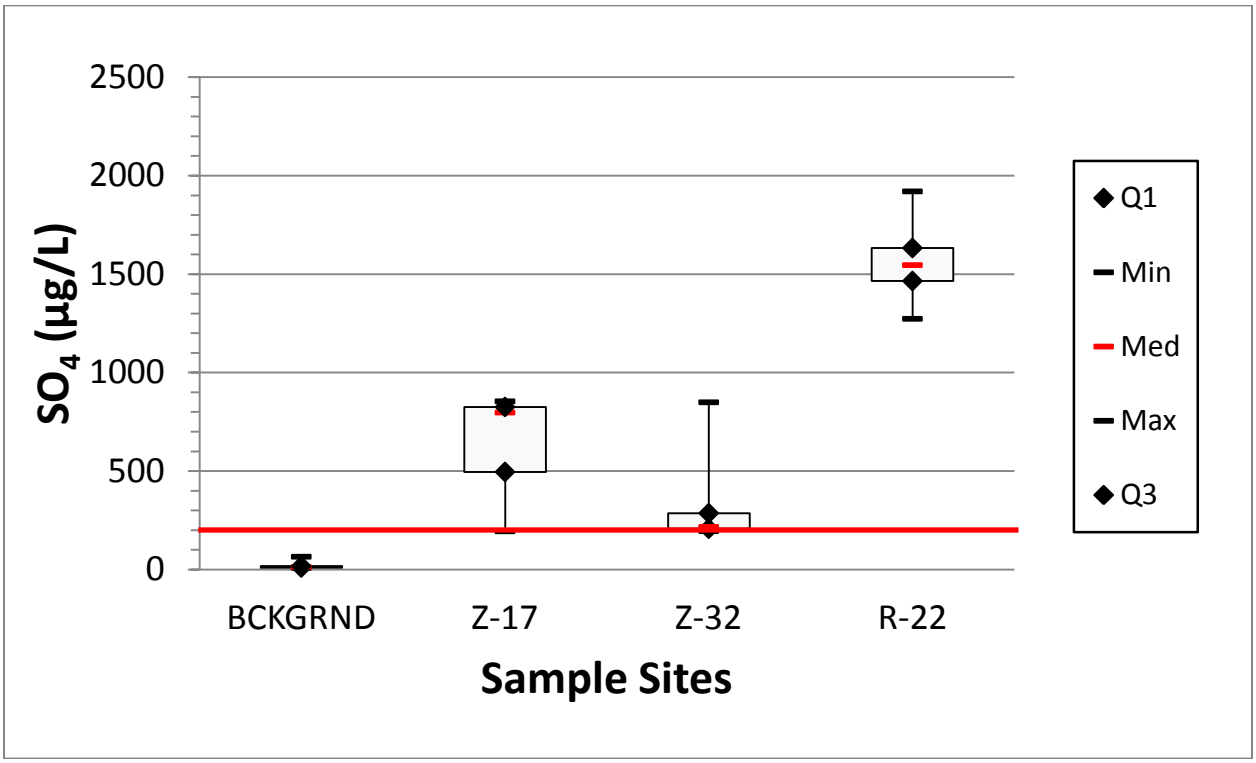

Figure F-18. Boxplot graph of Ruby Creek sulfate concentration at sites Z-17, Z-32, and R-22 compared to background levels and the sulfate indicator value of 200 µg/L

F 2.10.4 Ruby Creek TMDL Development Conclusions

The single Al result of less than 100 µg/L is not sufficient to assess compliance with the CAL criterion of 87 µg/L. Despite the basis of the 2000 listing on a total recoverable concentration and the possibility that background Al levels may exceed the CAL criterion during high flows, the previous listing, small dataset, and age of the data (1998) justify development of an alumium TMDL.

The CAL criteria for cadmium are exceeded in 3 of 43 samples having adequate MDLs. These same samples are also more than double the AAL criteria. Although the data suggest that background Cd concentrations may occasionally exceed CAL criteria during high flow, the magnitude of the exceedances at current condition sites require a cadmium TMDL. As with cadmium, the exceedance rates for the copper CAL and AAL criteria are less than 10 percent, but include values that exceed the HH criterion and are twice the AAL criterion. Thus, the data show a need for a copper TMDL. The CAL criteria for lead are exceeded in 30 percent of the samples, indicating the need for a lead TMDL. All 12 of the mercury results exceed the CAL criteria, indicating that a mercury TMDL is needed. Thirty-seven of 44 selenium results (84%) exceed the CAL criterion, include many HH exceedances, and indicate the need for a selenium TMDL. Three of 44 Zn results exceed the HH criterion and exceed the aquatic life criteria by greater than a factor of two, indicating the need for a Zn TMDL. To summarize, TMDLs will be developed for the following metals in Ruby Creek: aluminum, cadmium, copper, mercury, lead, selenium, and zinc. The TMDL for cadmium serves as a surrogate to address the pH listing.

F 2.11 SULLIVAN CREEK (MT40E002_110)

Sullivan Creek is the west branch of the Rock Creek headwaters at the Landusky Mine. The stream currently extends from the base of the L91 leach pad dike to its confluence with Rock Creek (**Figure F-19**).

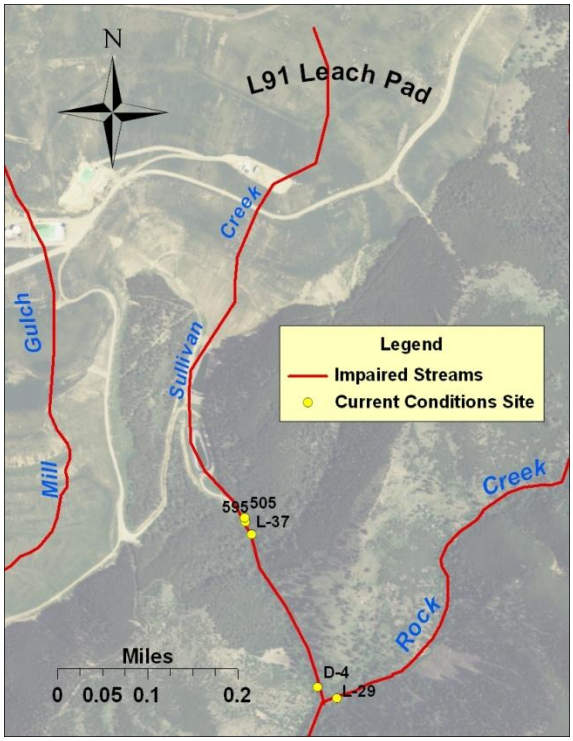

Figure F-19. Sullivan Creek (center), and current condition sites 505, 595, L-37, and D-4

Sullivan Creek is listed in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) as impaired by flow alterations, stream-side vegetative alterations, fish passage barriers, and substrate habitat alterations. A review of the Sullivan Creek water quality data determined that impairment is also caused by the metals cadmium, iron, lead, selenium and zinc. Current water quality conditions are represented by the records for sites 505, 595, D-4, and L-37. Background water quality is represented by sites Z-60, Z-61,and Z-62 in upper Alder Gulch, site RCSS-5 in upper Rock Creek, and site L-40 in upper Montana Gulch.

F 2.11.1 Sullivan Creek Sources

The main source of metals loading to Sullivan Creek is the L91 leach pad and supporting dike. The upper 50 percent of the pre-mine drainage of Sullivan Creek is occupied by the L91 dike, consisting of 3.8 million tons of waste rock fill, and the leach pad, containing 65 million tons of ore (Spectrum Engineering, Inc., 2006). Both structures were built from sulfide materials. The Sullivan Creek capture system and heated pump house were constructed at the base of the L91 dike and have operated since September, 1997. Captured seepage is stored in a lined, 1.8 million gallon holding pond built in the drainage bottom. Stored water is pumped to the Landusky treatment plant. Other Sullivan Creek sources include storm runoff from the dike and pad face and from local roadways.

F 2.11.2 Sullivan Creek Parameter Departures

Cadmium

There are 34 cadmium results, dating from 1995 to 2010, for the four current condition sites in Sullivan Creek. Two of these results are reported with MDLs greater than the CAL criteria. The criteria exceedance summary is provided in **Table F-33**.

Table F-33. Cadmium criteria exceedance numbers and percentage rates under high and low flow conditions at sites 505, 595, L-37, and D-4 in Sullivan Creek

Flow Conditions	Sample Size (CAL/AAL/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	21/22/22	8	38	2	9	2	9
Low Flow	11/12/12	3	27	0	0	0	0
All Flows	32/34/34	11	34	2	6	2	6

The CAL exceedance rate is greater than 10 percent and the record includes two high flow HH exceedances for the current condition sites. The CAL exceedance rate and occurrence of HH exceedances require a cadmium TMDL.

Among the background condition sites, nine results had MDLs above the CAL criteria, with one exceedance. Thirteen results are available from the background sites for comparison with AAL and HH criteria, and there are no exceedances.

Iron

There are 27 iron results for three of the four existing condition sites. Results for iron are not available for site 505. The exceedance summary for iron is provided in **Table F-34**.

Table F-34. Iron criteria exceedance numbers and percentage rates under high and low flow conditions at sites 595, L-37, and D-4 in Sullivan Creek

Flow Conditions	Sample Size	Aquatic Life Criterion Exceedance	
		Number	%
High Flow	17	2	12
Low Flow	10	2	20
All Flows	27	4	15

The rate of exceedance of the 1,000 µg/L aquatic life criterion is 15 percent across both flow conditions, requiring an iron TMDL for Sullivan Creek. Low flow exceedances occur at nearly twice the rate of high flow exceedances. Among 13 results for iron at the background sites, there is one high flow exceedance at site RCSS-5 in upper Rock Creek.

Lead

There are 30 results for lead among three of the four current condition sites. The lead exceedance summary is provided in **Table F-35**.

Table F-35. Lead criteria exceedance numbers and percentage rates under high and low flow conditions at sites 505, L-37, and D-4 in Sullivan Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	18	6	33	0	0	4	22
Low Flow	12	3	25	0	0	2	17
All Flows	30	9	30	0	0	6	20

The overall CAL exceedance rate is 30 percent and there are six exceedances of the HH criterion. Thus, a lead TMDL is required for Sullivan Creek. Among the background sites, lead was not detected in any of the five results reported with MDLs low enough for comparisons with CAL criteria. There are 13 results for lead reported with MDLs greater than the AAL criteria. Lead is not detected in any of these 13 samples.

Selenium

There are 30 selenium results available from sites 595, L-37, and D-4, for both high and low flow conditions. For the 15 samples collected from the current condition sites during the past decade, two results (13%) exceeded the CAL criterion during high flow. With the exceedance rate greater than 10 percent, a selenium TMDL is required for Sullivan Creek. The four most recent (2008-2010) high flow selenium results indicate that selenium concentrations commonly exceed the CAL criterion below the capture system. No results exceeded either the AAL or HH criteria for selenium at current condition sites. Among 15 selenium results available from the five background sites, there is one high flow CAL exceedance. The most recent samples for the background sites were collected in 1998.

Zinc

There are 34 zinc results available from the four current condition sites. The exceedance summary is provided in **Table F-36**.

Table F-36. Zinc criteria exceedance numbers and percentage rates under high and low flow conditions at sites 595, L-37, and D-4 in Sullivan Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	22	4	18	4	18	0	0
Low Flow	12	1	8	1	8	0	0
All Flows	34	5	15	5	15	0	0

Fifteen percent of the zinc results from current condition sites exceeded the CAL criteria, requiring a zinc TMDL for Sullivan Creek. Most exceedances occur during high flows. Three of the four aquatic life exceedances were more than double the value of the criteria. There are no exceedances among the13 zinc results available from the five background sites.

F 2.11.3 Sullivan Creek Supplemental Indicators

There is no sediment chemistry or macroinvertibrate metric data available for Sullivan Creek. **Figure F-20** illustrates the sulfate data distributions for each current condition site and the combined background sites. The plots indicate the effects of ARD on sulfate concentrations downstream of site 505 and the effects of dilution at site D-4 just above the confluence with Rock Creek.

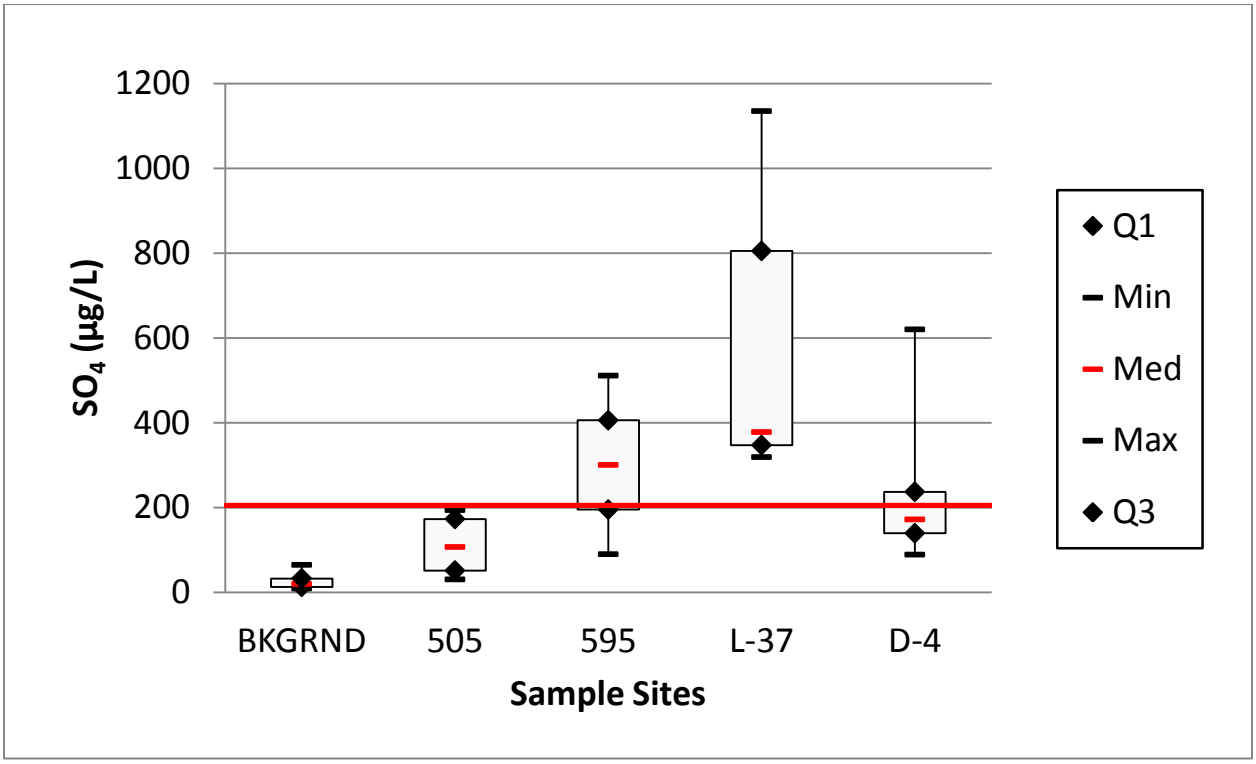

Figure F-20. Boxplots of sulfate data distributions for current condition sites and combined background sites for Sullivan Creek

F 2.11.4 Sullivan Creek TMDL Development Conclusions

The exceedance rates for at least one of the aquatic life criteria are greater than 10 percent for cadmium, iron, lead, selenium, and zinc. The HH criteria are exceeded for both cadmium and lead. Over half of the selenium data points are over 10 years old. The four most recent (2008-2010) high flow Se

results indicate that selenium concentrations commonly exceed the CAL criterion below the capture system. Sulfate concentrations also indicate the effects of ARD below the capture system. The data support development of TMDLs for cadmium, iron, lead, selenium and zinc in Sullivan Creek.

F 2.12 Swift Gulch Creek (MT40I002_010)

Swift Gulch Creek is listed as impaired in the 2010 Integrated Report (Montana Department of Environmental Quality, Water Quality Planning Bureau, 2010) for aluminum, arsenic, cadmium, copper, cyanide, iron, lead, nickel, thallium, zinc, and pH. The segment is classified as B-1 and extends for 1.7 miles from its headwaters to its confluence with South Big Horn Creek. Current water quality conditions are represented by sites BKSS-2, BKSS-3, BKSS-9, L-19, L-49, and M37SWFGC01 (**Figure F-21**).

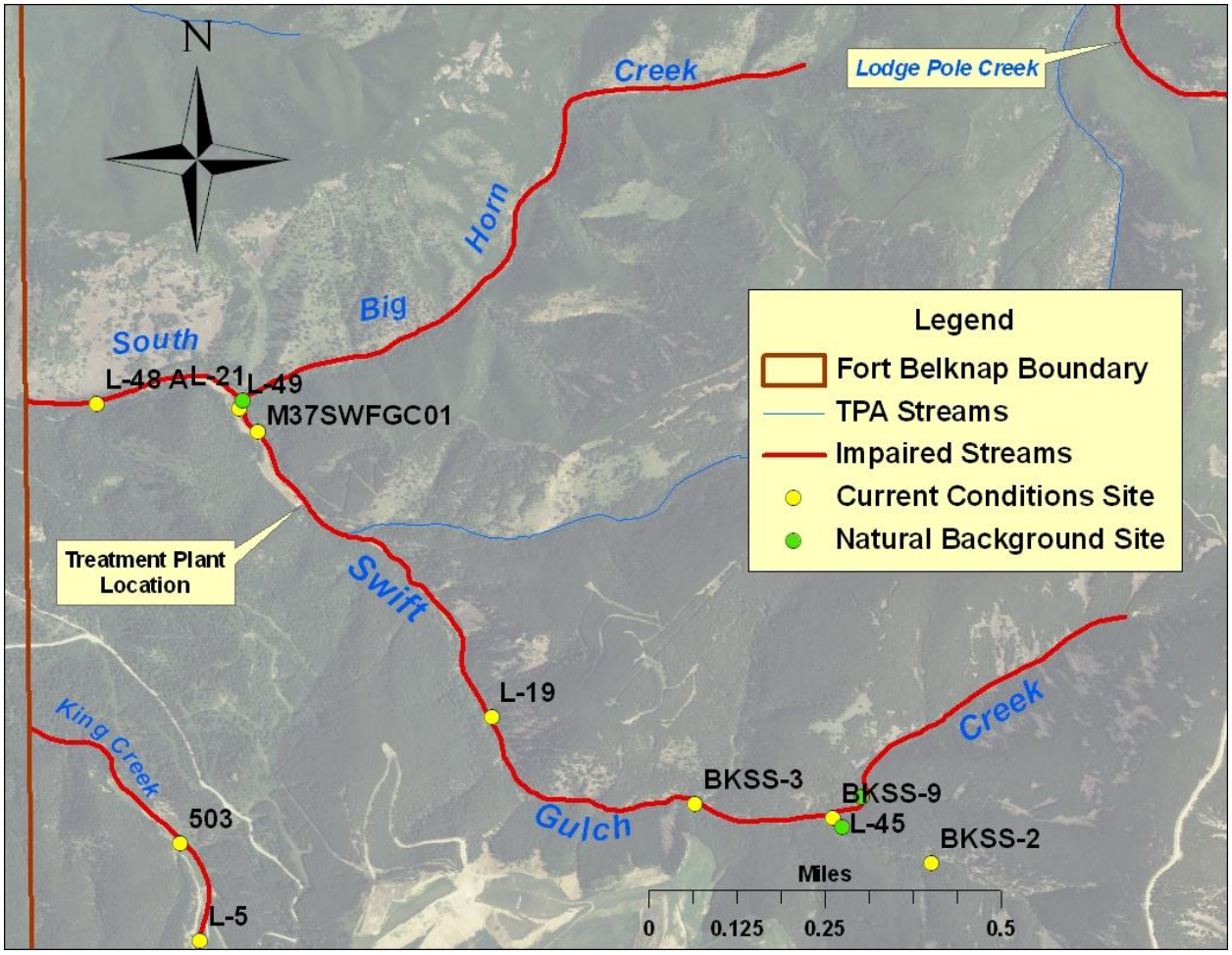

Figure F-21. Swift Gulch Creek and locations of current condition sites BKSS-2, BKSS-3, BKSS-9, L-19, L-49, and M37SWFGC01, and natural background sites L-21, L-41, and L-45.

F 2.12.1 Swift Gulch Creek Sources

The principal source of metals loading to Swift Gulch Creek is ARD-affected groundwater beneath the August-Little Ben-Surprise-Queen Rose pit complex at the Landusky Mine. The oxidation of sulfide rocks in and below the pit area causes acidification of local groundwater that is connected to Swift Gulch Creek surface water through a southwest-to-northeast trending shear zone. The ARD-affected groundwater enters the creek through several springs along the streambank between sites BKSS-9 and

L-19. Mining along the ridge on the south side of the gulch resulted in approximately 30 acres of disturbed area draining north into the gulch. Conceivable sources of cyanide to Swift Gulch Creek include the L87 and L91 leach pads constructed at the crest of the ridge on the south side of the gulch.

Deteriorating water quality in Swift Gulch Creek prompted construction of a third lime infusion treatment plant in 2010. The plant, located 300 meters upstream of the South Big Horn Creek confluence, is designed to treat ARD affected water at a rate of from 50 to 100 gallons per minute and return treated water to the stream channel. Extremely high precipitation and streamflow during the spring of 2011 disrupted the two capture systems upstream of the plant. Plant operations have been suspended pending repair of the capture systems.

F 2.12.2 Swift Gulch Creek Parameter Departures

Aluminum

Among the five existing condition sites, there are 22 results for dissolved aluminum in samples having a pH range from 6.5 to 9.0. The sample dates range from 1996 to 2009. Sixteen of the 22 samples have MDLs that exceed the CAL aluminum criterion of 87 µg/L. All six aluminum results with positive detections exceed the CAL criterion. Dissolved aluminum in the remaining six results ranges from 100 to 590 µg/L. All results greater than 100 µg/L are for high flow samples. An aluminum TMDL is required for Swift Gulch Creek

There are 15 results for dissolved aluminum from the three background sites. Eleven are less than the 100 µg/L detection limit. The remaining four samples each contain 200 µg/L and were collected during high flow.

Arsenic

There are 195 results for arsenic among the six existing condition sites. The sample dates occur between 1986 and 2011. **Table F-37** summarizes the arsenic exceedance record for these sites..

Table F-37. Arsenic criteria exceedance numbers and percentage rates under high and low flow conditions at sites BKSS-2, BKSS-3, BKSS-9, L-19, L-49, and M37SWFGC01 in Swift Gulch Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	85	0	0	0	0	41	48
Low Flow	110	0	0	0	0	71	65
All Flows	195	0	0	0	0	112	57

The 10 µg/L HH criterion is exceeded in 112 of 195 samples (57%), indicating the need for an arsenic TMDL for Swift Gulch Creek. Most As exceedances occur under low flow conditions. The CAL and AAL criteria were not exceeded in any sample. There were no arsenic criteria exceedances among 35 samples available for the three background sites.

Cadmium

There are 176 cadmium results for the six existing condition sites. Method detection limits in excess of the CAL and AAL criteria result in smaller sample sizes compared to that for the HH criterion. The exceedance summary is provided in **Table F-38** for each of the three criteria.

Table F-38. Cadmium criteria exceedance numbers and percentage rates under high and low flow conditions at sites BKSS-2, BKSS-3, BKSS-9, L-19, L-49, and M37SWFGC01 in Swift Gulch Creek

Flow Conditions	Sample Size (CAL/AAl/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	74/79/80	60	81	25	32	10	14
Low Flow	89/96/96	79	89	6	8	5	5
All Flows	163/175/176	139	85	31	26	15	8

Exceedance rates for both CAL and AAL criteria are greater than 10 percent and 15 results exceed the HH criterion. Eight results were more than double the AAL criteria. A TMDL for cadmium is required for Swift Gulch Creek. The AAL and HH criteria were more often exceeded during high flow conditions.

Among the three background condition sites, two samples in 25 exceeded the CAL criteria. Samples from background sites did not exceed either the AAL or HH criteria.

Copper

There are 176 copper results available for the six current condition sites. The exceedance summary is provided in **Table F-39**. The exceedance rates of both the CAL and AAL criteria are greater than 10 percent. Two results were more than double the AAL criteria and two results exceeded the HH criterion. Thus, a copper TMDL is required for Swift Gulch Creek.

Table F-39. Copper criteria exceedance numbers and percentage rates under high and low flow conditions at sites BKSS-2, BKSS-3, BKSS-9, L-19, L-49, and M37SWFGC01 in Swift Gulch Creek

Flow Conditions	Sample Size (CAL/AAl/HH)	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	77/79/80	21	27	21	27	0	0
Low Flow	96/96/96	19	20	6	6	2	2
All Flows	173/175/176	40	23	27	15	2	1

Of the 32 copper results for the three background sites that have MDLs less than the CAL criteria, three (9%) exceeded the CAL criteria during high flows. The same three samples also exceeded the AAL criteria. There were no HH exceedances among samples from the background sites.

Cyanide

Among five of the six current condition sites there are 133 cyanide results dated from 1997 to 2007. Of this dataset, 125 results are less than the MDLs. The eight positive detections occurred from 1998 through 2003 and are distributed among the five sites. All exceed the 5.2 µg/L CAL criterion. The most recent detection, 75 µg/L at site BKSS-3 in March of 2003, is more than double the AAL criterion of 22 µg/L. This result requires a cyanide TMDL for Swift Gulch Creek. There have been 47 non-detections among three of the sites from March, 2003, through May of 2007. Cyanide has not been detected in 29 samples collected from the three background sites.

Iron

The iron dataset includes 196 results from the six current condition sites. There are 48 exceedances among 88 high flow results (55%) and 66 exceedances among 108 low flow results (61%). These exceedance rates require an iron TMDL for Swift Gulch Creek. The corresponding dataset from the background sites contains 10 results from two sites with one high flow exceedance.

Lead
There are 61 results for lead among three of six current conditions sites over the most recent 10-year period. Forty-seven of these results are less than MDLs. Of the 14 positive detections, none have exceeded water quality criteria. Therefore, a lead TMDL is not developed for Swift Gulch Creek.

Nickel
There are 169 results for nickel from five of the six current condition sites. The exceedance summary for nickel is provided in **Table F-40.**

Table F-40. Nickel criteria exceedance numbers and percentage rates under high and low flow conditions at sites BKSS-3, BKSS-9, L-19, L-49, and M37SWFGC01 in Swift Gulch Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	70	11	16	0	0	19	27
Low Flow	99	48	48	0	0	51	52
All Flows	169	59	35	0	0	70	41

The CAL exceedance rate is greater than 10 percent, with most exceedances occurring during low flow. There are 70 HH exceedances, also predominantly during low flow. A nickel TMDL is required for Swift Gulch Creek.

There are 30 Ni results among the three background sites during the past 10 years. Twenty-eight of these have been less than MDLs. The two positive detections are less than all applicable criteria.

Selenium
There are 103 results for selenium from five of six current conditions sites during the most recent 10 years. Water quality criteria have not been exceeded in any sample. There are 33 selenium results during the past 10 years from the three background sites with one CAL exceedance. A selenium TMDL is not required for selenium in Swift Gulch Creek.

Thallium (Tl)
There are four results for thallium from samples collected at four current condition sites in 1996 and 1997. All are less than the MDL of 3 µg/L. The listing probably stems from an interpretation of these results as positive detections in a dataset that often lacks quality control flags. The detection limit of 3 µg/L is greater than the HH criterion of 0.24 µg/L. Given the previous listing and age of the thallium dataset, a thallium TMDL is developed for Swift Gulch Creek.

Zinc
There are 173 results for Zn obtained from five of the six current condition sites. The exceedance record is summarized in **Table F-41**.

Table F-41. Zinc criteria exceedance numbers and percentage rates under high and low flow conditions at sites BKSS-3, BKSS-9, L-19, L-49, and M37SWFGC01 in Swift Gulch Creek

Flow Conditions	Sample Size	CAL Exceedance		AAL Exceedance		HH Exceedance	
		Number	%	Number	%	Number	%
High Flow	76	49	64	49	64	2	3
Low Flow	97	63	65	63	65	35	36
All Flows	173	112	65	112	65	37	21

Aquatic life exceedances for Zn are greater than 10 percent of samples and the dataset includes 37 HH exceedances. Therefore, a zinc TMDL is required for Swift Gulch Creek. There are 37 Zn results among the three background sites. No water quality criteria for Zn are exceeded in any of these samples.

F 2.12.3 Swift Gulch Creek Supplemental Indicators

Sulfate

Figure F-22 illustrates the sulfate concentration record for site L-19 in Swift Gulch Creek. The data show a marked increase during 1990 above initial single digit values. The 200 µg/L indicator value first was first exceeded in 1995. The graph illustrates the worsening effect of ARD, interrupted by periodic high flow dilution.

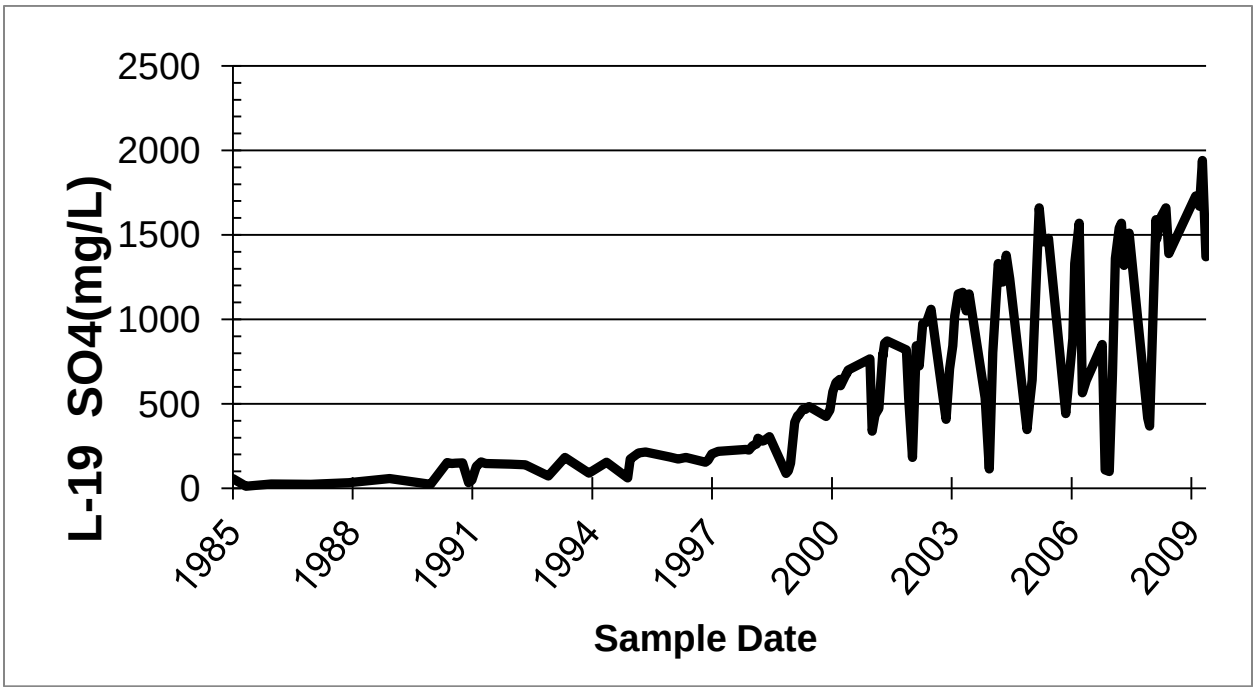

Figure F-22. Sulfate concentration in Swift Gulch Creek surface water at site L-19

There are no available sediment chemistry data for Swift Gulch Creek. A macrovertibrate assessment completed for a sample collected at site MT37SWFGC01 in 2005 had a low valley MMI score of 72.4, that meets the minimum indicator value of 48. The sample scored a RIVPACS score of 0.79, just below the 0.8 target value

F 2.12.4 Swift Gulch Creek TMDL Development Conclusions

The exceedance rates for either the CAL or AAL criteria are greater than 10 percent for cadmium, copper, iron, nickel, and zinc. The MDLs for dissolved aluminum are greater than the CAL criterion. All six positive detections for dissolved aluminum exceed the CAL criterion. Fifty-seven percent of arsenic results exceed the HH criterion. A March, 2003, result of 75 µg/L for cyanide is more than double the 22 µg/L AAL criterion. Despite the possible false positive result for thallium, the MDL reported with the thallium results is greater than the HH criterion. The criteria exceedance rates or the uncertainty introduced by high MDLs for previously listed impairment causes, support TMDL development for aluminum, arsenic, cadmium, copper, iron, nickel, thallium, and zinc. Cadmium will serve as a surrogate parameter to address the pH impairment. The datasets for the previously listed causes lead and selenium have aquatic life exceedance rates of less than 10 percent and contain no HH exceedances. The data do not support the need for either lead or selenium TMDLs.

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