Appendix B: Additional technical details – Mountain Studies Institute's 2017 water quality monitoring analysis

Water Quality Benchmarks: Iron and aluminum chronic water quality standards

In 2017, concentrations of iron and aluminum reached levels of concern for long term exposure to aquatic life. CDPHE provides acute water quality standards that are set to be protective of aquatic life from brief, short-term exposure to contaminants. The aluminum concentration on June 6, 2017 (2,480 ug/L) surpassed the hardness based acute aquatic life standard (2,119 ug/L). CDPHE specifies that the paired hardness concentration must surpass the acute standard more than once in a three-year period for a legitimate exceedance of an acute standard to have occurred (CDPHE 2017). Although the concentration of aluminum in the Animas river at Rotary Park did not surpass the acute aquatic life standard in 2016, the concentration of aluminum did surpass the standard on August 7, 2015 from samples collected during the Gold King Mine release (Roberts 2016).

CDPHE provides chronic water quality standards that are set to be protective of aquatic life from persistent, long-term exposure to contaminants. CDPHE evaluates chronic aluminum impairment by two methods (CDPHE 2015). The first method compares the 85th percentile of total aluminum concentration values to a chronic standard based on an average hardness value. For the 2017 Rotary Park data, the 85th percentile was 1,320 ug/L, which surpasses the average hardness based standard of 707 ug/L. The second method assigns a chronic standard for each sample based on the hardness value observed at the time the sample was collected. Impairment is designated if 50% of the samples exceed their paired chronic standard. For the 2017 Rotary Park data, 8 of 21 samples (38%) surpassed their paired chronic standard for aluminum, which is less than the 50% threshold that would designate impairment. CDPHE considers the second method (paired hardness-concentrations) more representative than the first method (based on average hardness) so although total aluminum concentrations were relatively high, they are not high enough to technically surpass the CDPHE chronic aquatic life standard for aluminum. The chronic aquatic life water quality standard for iron is evaluated based on the median observed value. The median value for total iron over the 2017 monitoring period was 466 ug/L, which is lower than the CDPHE chronic aquatic life standard of 1,000 ug/L (CDPHE 2017). Iron concentrations at Rotary Park in 2016 were high enough to surpass the CDPHE chronic aquatic life standard.

2017 Water Quality Data in Context of Historical Data: Summary statistics and statistical analysis

MSI compared Animas River metal concentrations in 2017 to those observed by River Watch from 2002 to 2014 (CDSN 2015) using a statistical test called Wilcoxon rank sum test. The results of the test indicate that there was no significant difference in the concentration of most metals of the Durango stretch of the Animas River in 2017 compared to the 2002-2014 time period (Table 1). Concentrations of dissolved copper and total zinc were significantly lower in 2017 than during 2002-2014.

Metals and Other Water Quality Parameters: Correlation statistics and an example graph of the four USGS water quality parameters: discharge, turbidity, pH, and conductivity

In 2016, USGS began to provide continuous measurement of pH, turbidity, and conductivity at their Animas River gauge in Durango, CO *(data available at https://waterdata.usgs.gov/nwis/uv?09361500)*. MSI examined the relationship between metal concentrations and these additional water quality parameters (Figures 1-4). Spearman correlation coefficients indicate that several metals correlated at a statistically significant level with discharge, turbidity, pH, and conductivity (Table 2).

Table 1: Summary statistics for metal concentrations observed in 2017 and for the River Watch data set (2002-2014). P values are test results of Wilcoxon rank sum test. Gold highlight indicate a statistically significant difference.

	ug/L	Al March-Aug 2017	Al March-Aug 2002-2014	Cu March-Aug 2017	Cu March-Aug 2002-2014	Fe March-Aug 2017	Fe March-Aug 2002-2014	Pb March-Aug 2017	Pb March-Aug 2002-2014	Zn March-Aug 2017	Zn March-Aug 2002-2014
Total	n	20	72	9.0	100	20	153	12	89	20	148
	Min	9.0	28	4.4	4.2	120	3.2	3.0	3.1	30	16
	Mean	639	599	10	13	989	1008	14	16	81	110
	Median	291	408	9.4	8.7	445	591	13	10	68	92
	95th	1568	1812	16	30	2526	3244	32	43	163	220
	Max	2480	3555	19	71	3770	9770	39	124	163	472
	p value	0.842		0.817		0.851		0.954		0.027	
Dissolved	n	*		14	20	*		*		20	74
	Min			1.0	1.5					26	11
	Mean			1.9	2.7					42	48
	Median			2.0	2.5					41	43
	95th			2.8	4.3					55	76
	Max			3.0	5.0					63	253
	p value			0.006						0.357	

*Dissolved aluminum, iron, and lead could not be included in statistical analysis due to the limited number of samples where concentrations were detected.

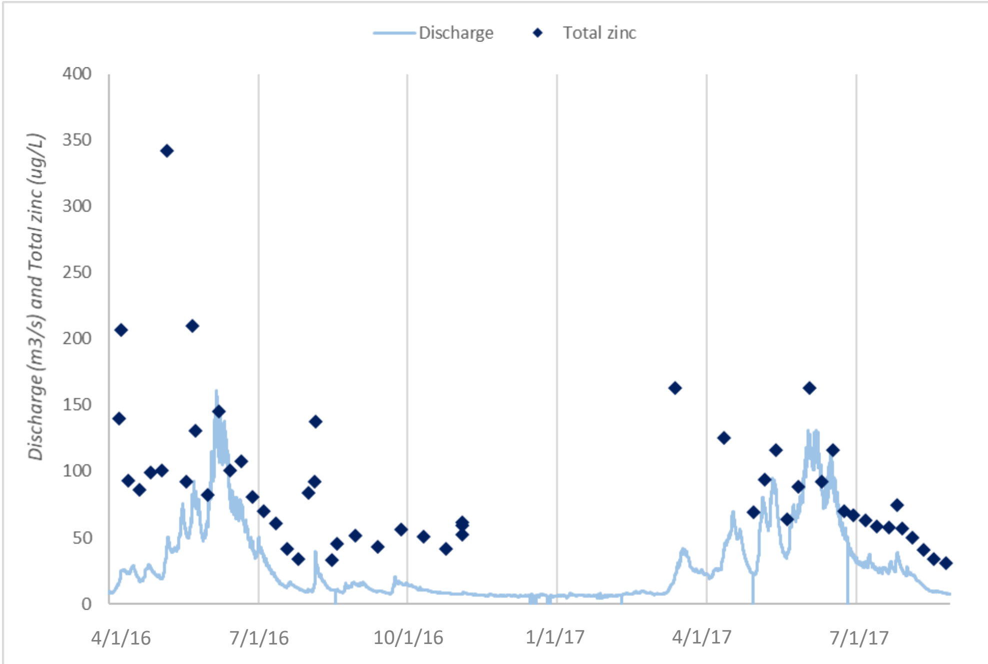

Figure 1: Discharge and total zinc.

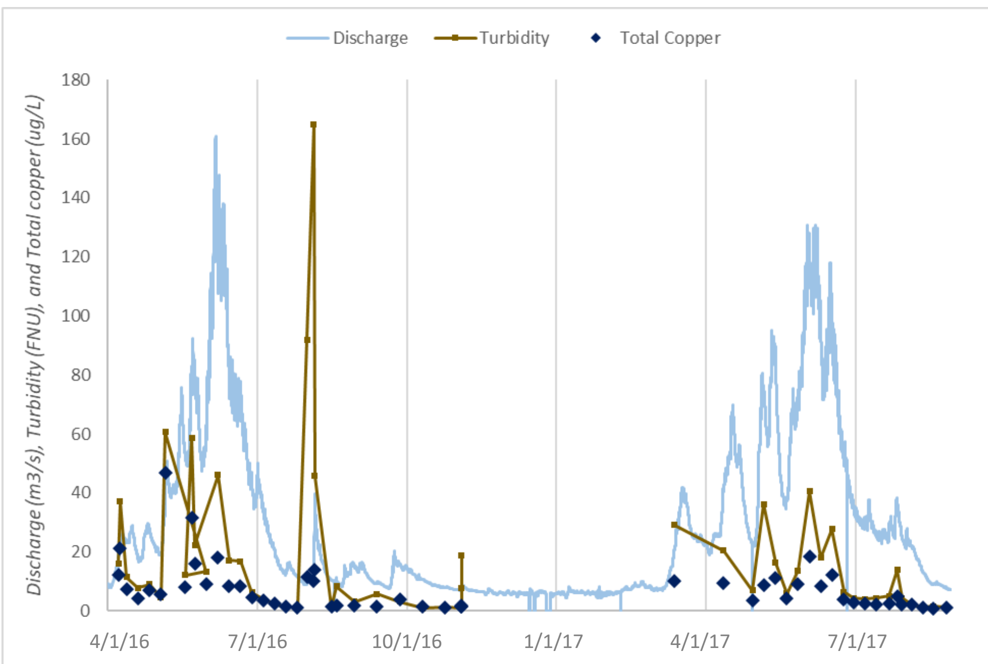

Figure 2: Discharge, turbidity, and total copper.

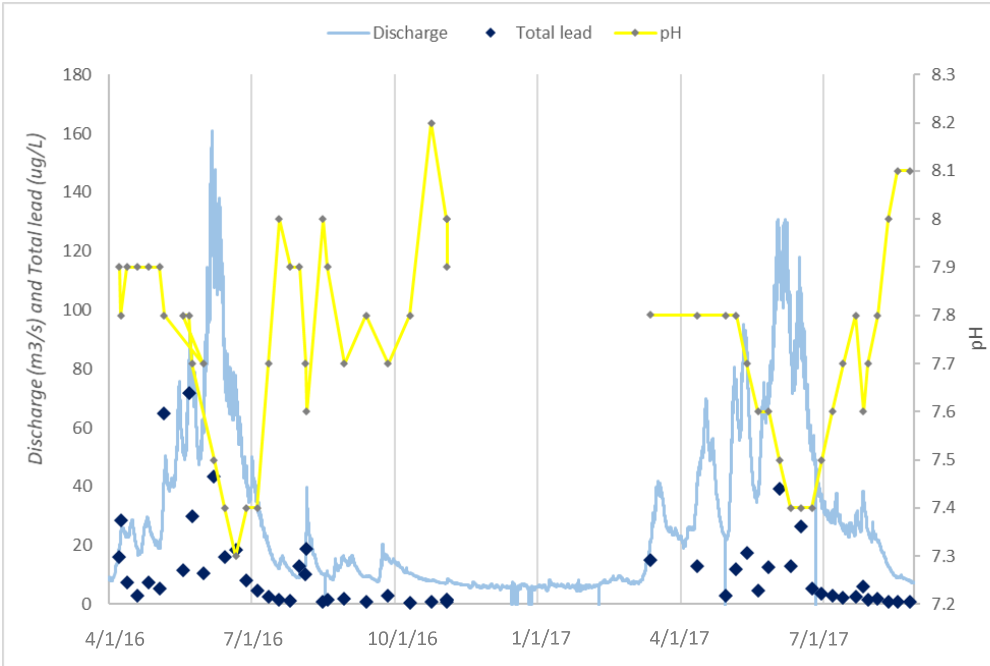

Figure 3: Discharge, pH, and total lead.

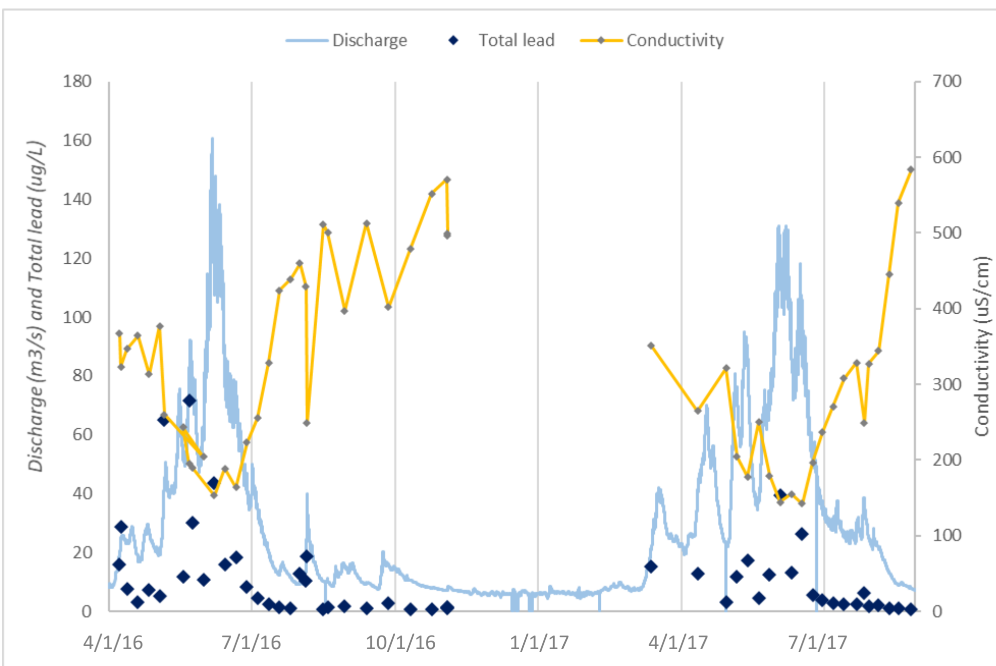

Figure 4: Discharge, conductivity and total lead.

Table 2: Spearman correlation coefficients for metal concentrations and water quality parameters measured in 2016 and 2017. Yellow highlight indicates a statistically significant correlation at the 0.05 alpha level

					Aluminum		Copper		Iron		Lead		Zinc	
					T	**D**	**T**	**D**	**T**	**D**	**T**	**D**	**T**	**D**
When…	*…discharge…*	*…increased…*	*…the following metals…*	*…increased*	0.70	*	0.73	0.78	0.69	*	0.81	*	0.70	
	…discharge…	*…increased…*		*…decreased*		*				*		*		-0.02
	…turbidity…	*…increased…*		*…increased*	0.87	*	0.88	0.58	0.89	*	0.86	*	0.84	
	…turbidity…	*…increased…*		*…decreased*		*				*		*		-0.40
	…pH…	*…decreased…*		*…increased*	-0.39	*	-0.47	-0.53	-0.40	*	-0.54	*	-0.42	-0.27
	…conductivity…	*…increased…*		*…decreased*	-0.66	*	-0.70	-0.77	-0.66	*	-0.79	*	-0.68	-0.07

*Dissolved aluminum, iron, and lead could not be included in statistical analysis due to the limited number of samples where concentrations were detected.

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