Appendix B: Additional technical details – Mountain Studies Institute's 2016 water quality monitoring analysis

Water Quality Benchmarks: Iron and aluminum chronic water quality standards

In 2016, concentrations of iron and aluminum reached levels of concern for long term exposure to aquatic life. CDPHE provides chronic water quality standards that are set to be protective of aquatic life from persistent, long-term exposure to metals. 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 2016 monitoring period was 1,115 ug/L, which is higher than the CDPHE chronic aquatic life standard of 1,000 ug/L (CDPHE 2017). 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 2016 Rotary Park data, the 85th percentile was 1,636 ug/L, which surpasses the average hardness based standard of 1,029 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 2016 Rotary Park data, 15 of 37 samples (41%) 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.

2016 Water Quality Data in Context of Historical Data: Summary statistics and statistical analysis

MSI compared Animas River metal concentrations in 2016 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 is no significant difference in metal concentration of the Durango stretch of the Animas River in 2016 compared to the 2002-2014 time period (Table 1).

Spring Runoff and Storm Events: Summary statistics and statistical analysis

MSI compared 2016 Rotary Park metal concentrations from opportunistic samples collected during changing river conditions (storm events or rapid river level rise) to samples collected at regular weekly and bi-weekly intervals during stable river conditions. Results from Wilcoxon rank sum tests indicate that there was a significant difference in metal concentrations measured during changing conditions compared to those measured during stable conditions (Table 2).

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 1-3). Spearman correlation coefficients indicate that several metals correlated at a statistically significant level with discharge, turbidity, pH, and conductivity (Table 3).

Table 1: Summary statistics for metal concentrations observed in 2016 and for the River Watch data set (2002-2014). P values are test results of Wilcoxon rank sum test.

	ug/L	Al		Cu		Fe		Mn		Pb		Zn	
		2016	2002-2014	2016	2002-2014	2016	2002-2014	2016	2002-2014	2016	2002-2014	2016	2002-2014
Total	n	27	120	15	126	27	236	27	236	16	105	27	239
	Min	62	26	4.3	4.2	109	66	65	20	3.1	3.1	33	8.5
	Mean	522	433	9	11	941	783	154	158	13	15	81	97
	Median	377	253	8.0	7.7	791	428	157	122	10	8.4	82	84
	95th	1412	1276	17	29	2607	2899	298	356	33	43	137	191
	Max	1680	3555	18	71	3190	9770	363	1084	44	124	145	472
	p value	0.120		0.686		0.180		0.539		0.561		0.290	
Dissolved	n							27	141			27	142
	Min							36	17			24	6.6
	Mean							74	99			44	54
	Median	*		*		*		68	72	*		46	53
	95th							124	226			56	85
	Max							154	791			59	253
	p value							0.383				0.030	

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

Table 2: Summary statistics for metal concentrations observed in 2016 during changing river conditions and during stable river conditions. P values are test results of Wilcoxon rank sum test. Yellow-highlight indicates statistical significance at the 0.05 alpha level.

	ug/L	Al		As		Cu		Fe		Mn		Pb		Zn	
		Stable	Storms	Stable	Storms	Stable	Storms	Stable	Storms	Stable	Storms	Stable	Storms	Stable	Storms
Total	n	27	10	27	10	27	10	27	10	27	10	27	10	27	10
	Min	62	111	0.20	0.20	1.30	0.60	109	188	65	81	0.60	1.00	33	46
	Mean	522	1868	0.52	1.43	5.79	14.23	941	3738	154	309	8.43	22.40	81	149
	Median	522	1885	0.50	1.05	4.50	10.95	791	3265	157	246	5.20	12.90	82	115
	95th	1412	4706	1.40	3.06	14.79	40.16	2607	8264	298	661	26.62	68.64	137	304
	Max	1680	5340	1.80	3.10	18.10	47.00	3190	8390	363	808	43.50	71.70	145	342
	p value	0.033		0.037		0.194		0.027		0.024		0.101		0.094	
Dissolved	n			27	10	27	10			27	10			27	10
	Min			0.20	0.20	0.60	0.70			36	14			33	11
	Mean			0.21	0.26	4.21	1.23			74	54			81	29
	Median	*		0.21	0.20	1.00	1.10	*		68	57	*		82	18
	95th			0.20	0.50	2.27	1.90			124	78			137	48
	Max			0.50	0.50	83.50	1.90			154	83			145	50
	p value			0.112		0.63				0.025				0.001	

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

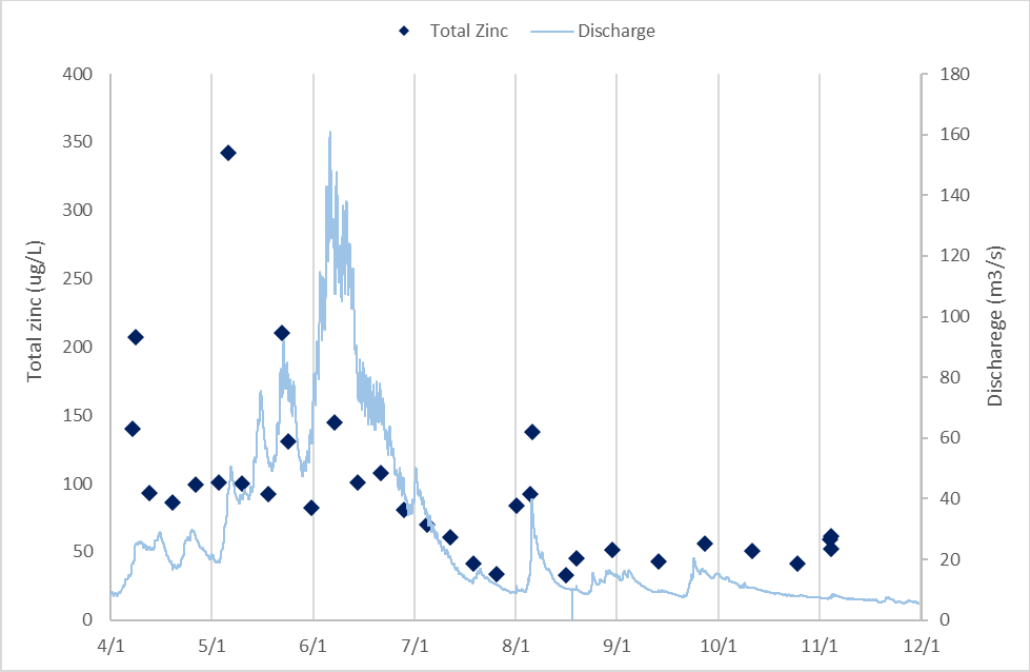

Figure 1: Discharge and total zinc.

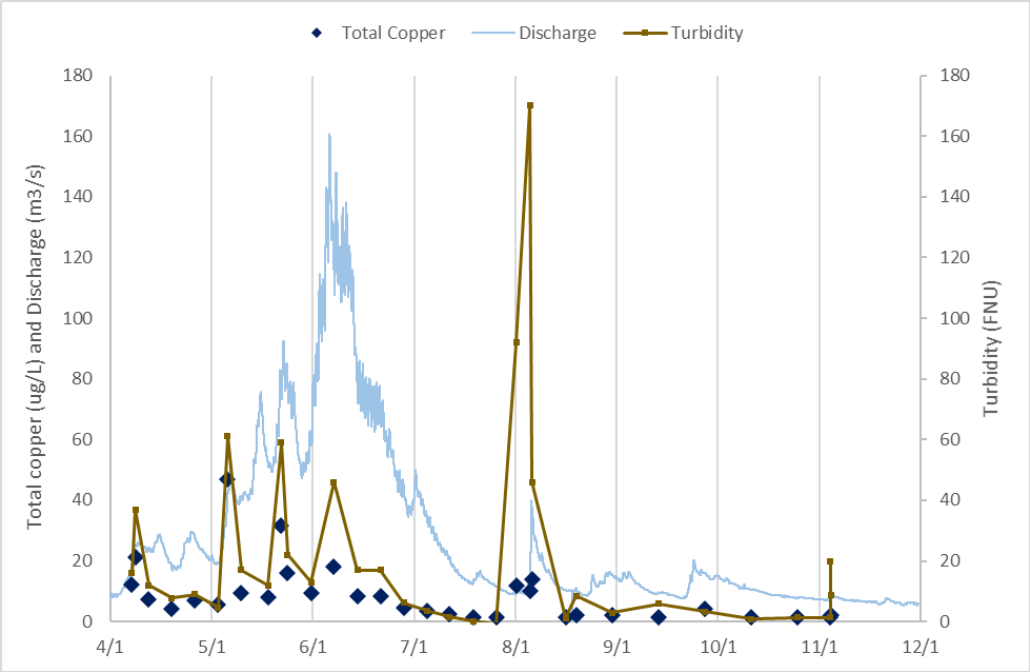

Figure 2: Turbidity and total copper.

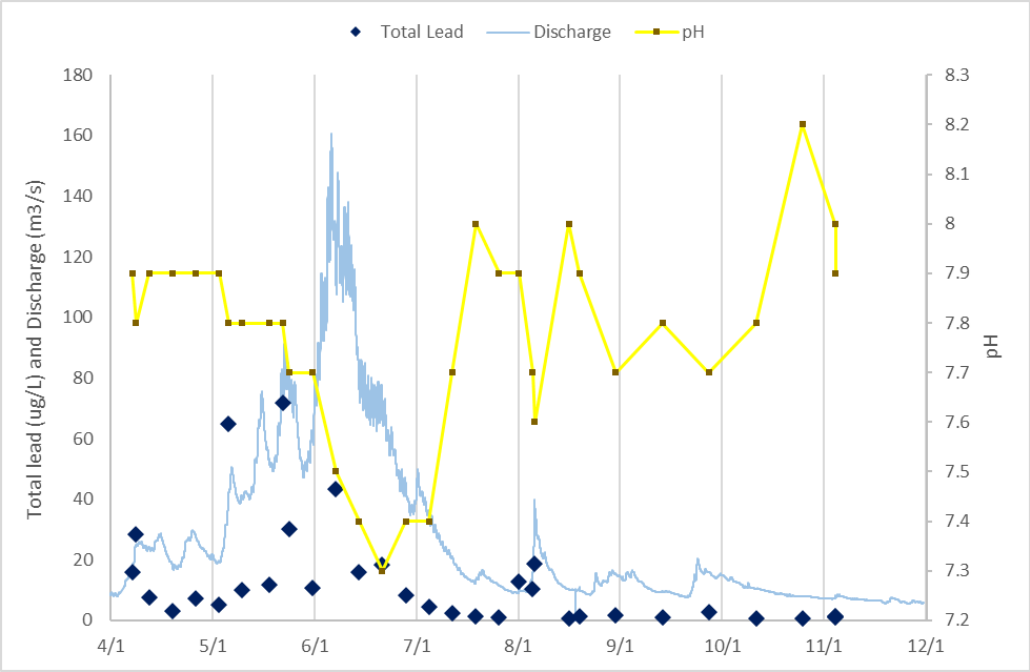

Figure 3: pH and total lead.

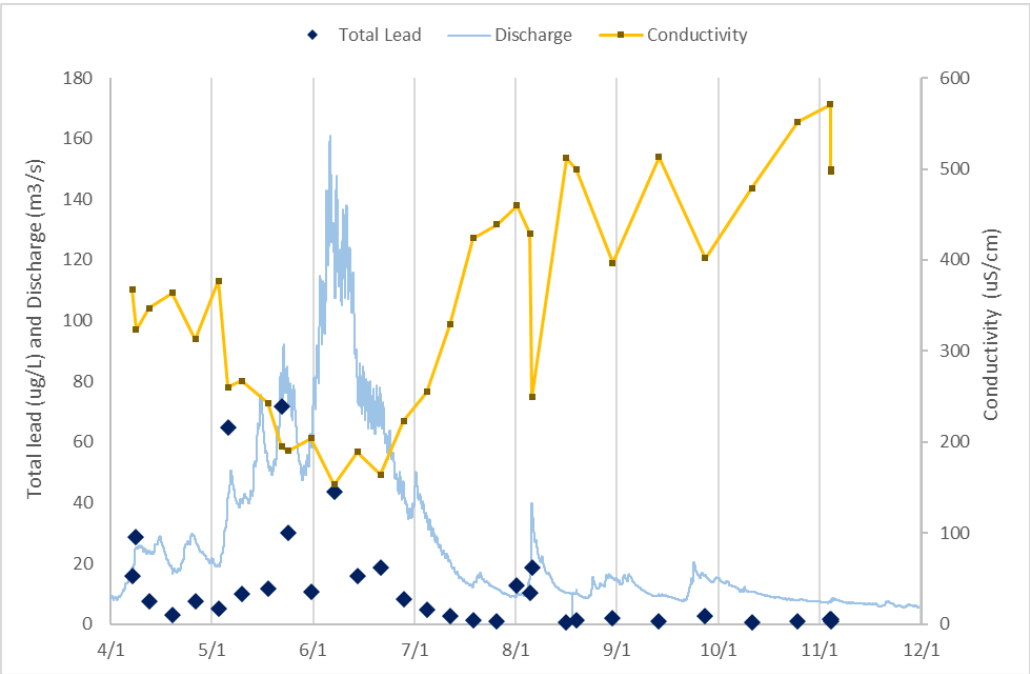

Figure 4: Conductivity and total lead.

Table 3: Spearman correlation coefficients. Yellow highlight indicates a statistically significant correlation at the 0.05 alpha level.

					Aluminum		Arsenic		Copper		Iron		Lead		Manganese		Zinc	
					T	D	T	D	T	D	T	D	T	D	T	D	T	D
When…	*...discharge…*	*...increased…*	*...the following metals…*	*...increased*	0.542	*	0.011	*	0.756	0.63	0.555	*	0.721	*	0.502		0.565	
	...discharge…	*...increased…*		*…decreased*		*		*				*		*		-0.28		-0.13
	...turbidity…	*...increased…*		*...increased*	0.826	*	0.581	*	0.861	0.397	0.852	*	0.815	*	0.857		0.787	
	...turbidity…	*...increased…*		*...decreased*		*		*				*		*		-0.46		-0.56
	...pH…	*...decreased…*		*...increased*	-0.39	*	-0.29	*	-0.75	-0.39	-0.42	*	-0.55	*	-0.48		-0.52	-0.1
	...pH…	*…increased…*		*…increased*		*		*				*		*		0.167		
	...conductivity…	*...decreased…*		*...increased*	-0.74	*	-0.02	*	-0.79	-0.6	-0.75	*	-0.86	*	-0.73		-0.73	
	...conductivity…	*…increased…*		*…increased*		*		*				*		*		0.401		0.224

*Dissolved aluminum, arsenic, 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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