DRAFT 09/19/2015

Historic, Current, and Predicted Metal Concentrations in the Animas River at A72 and Bakers Bridge

1.0 BACKGROUND

The Gold King Mine is located approximately 10 miles north of Silverton, San Juan County, Colorado. Approximately 3 million gallons of mining-impacted water were released from the Gold King Mine on August 5, 2015. The water flowed across a waste rock dump to North Fork, Cement Creek, and the Animas River. Over the next several days orange water was observed for many miles downstream. As of September 11, 2015 the Gold King Mine continued to discharge approximately 560 gallons per minute (gpm) of acid mine drainage. Mine discharges ranged from 12 gpm to 250 gpm from 2009 through 2015.

This document, prepared with input from EPA and the U.S. Geological Survey (USGS), presents information related to the potential impacts of the increased discharge from the Gold King mine to water quality at specific downstream locations. Sections 2 through 4 present and compare current and historic (2009-2014) water quality measured in the Animas River downstream of Silverton. Sections 5 and 6 provide discussion of topics that may impact downstream concentrations such as pH, hardness, and attenuation. Sections 7 and 8 describe the methods used to estimate contaminant concentrations that might occur at two locations downstream of Silverton through the winter with the added Gold King Mine flow. Predicted concentrations are presented. Hazard quotients that indicate the potential impacts to aquatic receptors are described in Section 9.

Certain measurement locations are referenced by long-term sample location identifiers. Sample locations referred to in this document include the following (USGS gauging station location shown in parentheses):

- CC06 Gold King Mine discharge
- CC48 Cement Creek above Silverton (09358550)
- A68 Animas River at Silverton (upstream of Cement Creek) (09358000)
- M34 Mineral Creek at Silverton (09359010)
- A72 Animas River below Silverton (09359020)
- Bakers Bridge Animas River at Bakers Bridge, approximately 30 miles downstream of A72 and 9 miles downstream of the Animas River at Tall Timbers Resort gauging station (09361500)

2.0 CURRENT WATER QUALITY

Water samples were collected daily at specific locations (CC48, A68, A72, and Bakers Bridge) from August 5-31, 2015, after the Gold King Mine release on August 5. Samples collected from August 5 through 10 show the spike and recovery that occurred immediately after the release. Samples collected after August 11, 2015 appear to best represent post-release concentrations and are referred to as “August 2015” samples in this document. Samples were collected approximately every other day from CC06 during August. Daily sampling at M34 began on August 29. Sampling continued past August 31 but the results are not part of this analysis.

August 2015 data for the Animas River downstream of Silverton (A72) are summarized on Table 1 and Graph Set 1. August 2015 data for the Gold King Mine discharge are summarized on Table 2.

3.0 COMPARE CURRENT TO HISTORIC (2009-2014) WATER QUALITY

A72 was sampled periodically by EPA from August 2009 through June 2015. August 2015 versus 2009-2014 water quality is summarized on Table 3. The Table 3 historic summary statistics include data from EPA monitoring events from 2009-2014 (using one monthly average when more than one sample was collected during a specific month) but do not include mini-sipper data. June 2015 data are not included in the summary statistics.

Comparison of current and historic A72 data shows the following:

- The August 2015 dissolved and total cadmium, iron, and zinc concentrations at A72 are within the range of concentrations measured from 2009-2014.

- The August 2015 dissolved copper concentrations are greater than the average and median historic concentrations but do not exceed the maximum 2009-2014 concentration. The August 2015 total copper concentrations exceed the maximum 2009-2014 concentration.

Historic (including EPA/ESAT sampling events from August 2009-June 2015 and mini-sipper data) and August 2015 cadmium, copper, iron, and zinc concentrations are shown on Graph Set 2. The historic concentrations are shown in blue and the average August 2015 concentration is shown as a red square. Note that the vertical gridlines on the graphs are aligned with August of each year to allow comparisons of current conditions to August of previous years. The last "historic data" point represents a sample collected during a storm event that occurred on June 10, 2015, one day after the primary sample was collected.

The graphs show the following:

- The August 2015 dissolved and total cadmium, iron, and zinc concentrations at A72 are within the range of concentrations measured from 2009-2015.

- There was a large jump in total metals concentrations during the June 2015 storm event. The total cadmium, copper, iron, and zinc concentrations for August 2010 were greater than the June 9, 2015 concentrations but lower than the June 10, 2015 storm event concentrations.

- The June 10, 2015 storm event dissolved metals concentrations were not higher than the June 9, 2015 concentrations.

4.0 RELATIVE FLOW AND LOAD CONTRIBUTIONS FROM PRIMARY SOURCES TO A72

Average daily flow at A72 during August 2015 ranged from 133 cubic feet per second (cfs) to 308 cfs with an average of 192 cfs, compared to the August average flow of 221 cfs and 25th percentile flow of 123 cfs for USGS Gauging Station 09359020, period of record from 1991-2014. February is the month with the lowest average monthly average flow at A72 (58 cfs); the 25th percentile flow during February is 48 cfs.

The relative flows and loads from the three primary source waters to A72 are shown on Table 4. Historic non-runoff samples were collected when A72 flows ranged from 57 to 250 cfs. The "current" values were from three days (August 29-31, 2015) because M34 samples were not collected until August 29. The percentages of the A72 cadmium, copper, and zinc loads that came from Cement Creek (CC48) in late August 2015 were greater than were measured during non-runoff events from 2009-2014; however, the percent of the A72 iron load from Cement Creek during late August 2015 was similar to the percentage observed from 2009-2014.

The loads of some metals from the three source waters were often greater than the load at A72, indicating that metals are dropping out in the river.

5.0 CEMENT CREEK LOADING AND CONCENTRATIONS – 2015 VERSUS OCTOBER 2012

Dissolved cadmium, copper, and zinc loads at the base of Cement Creek (CC48) during August 2015 are elevated over the loads during a time of similar flow, October 2012 (Graph Set 3). If the Gold King Mine load was eliminated, the August 2015 Cement Creek load would be similar to or slightly greater than the October 2012 load.

Dissolved cadmium, copper, iron, and zinc concentrations in Cement Creek upstream and immediately downstream of the Gold King Mine discharge inflow and at the base of Cement Creek are shown on Graph Set 4. The 2015 cadmium, copper, and zinc concentrations are much greater than the 2012 concentrations immediately downstream of the Gold King Mine inflow; however, the increase is much less pronounced at the base of Cement

Creek. Note that the 2015 dissolved iron concentrations in Cement Creek are lower than were observed during 2012, and the dissolved zinc concentration at the base of Cement Creek is similar to the 2012 concentration.

6.0 PH AND HARDNESS CONSIDERATIONS

Water pH can affect the behavior of metals in the river. Metals concentrations at downstream locations may be reduced by precipitation and sorption due to increasing pH as well as by dilution from inflows to the river. The variation of pH from upstream to downstream for historic (2013 and 2014) and current events is shown on Table 5 and Graph Set 5. All locations are in the Animas River except inflows that are shaded in the table and shown with hollow bars on the graphs. pH increases as the river flows downstream south of Silverton.

Stream pH may also vary from month to month. Average monthly concentrations measured by Colorado River Watch at A72 and Bakers Bridge over a number of years are shown in Graph Set 6. Average monthly pH at A72 varies over the year with lower pH measured during winter months when Animas River flow is low. Despite the variability in A72 pH, the average monthly pH at Bakers Bridge remains relatively constant.

Hardness can affect fish toxicity and many aquatic life water quality standards for metals are hardness-based. Metals are often more toxic to aquatic life when the water has lower hardness. Hardness measured at A72 and Bakers Bridge over time by Colorado River Watch is shown on Graph Set 7. Hardness at both locations is the greatest during winter months and the lowest during spring runoff. The average winter hardness at A72 is 300 milligrams per liter (mg/L) and the average winter hardness at Bakers Bridge is 175 mg/L.

7.0 PREDICTED METAL CONCENTRATIONS AT A72

Metal concentrations at A72 were predicted in two ways. First, historic data were used to estimate A72 concentrations that would have occurred given contaminant contribution from the additional flow from the Gold King Mine. Second, the August 2015 load of contaminants at A72 was "concentrated" using the average monthly flows at A72.

1) Metal concentrations that might have been expected at A72 during historic sampling events with the addition of the increased flow from the Gold King Mine discharge were estimated using the following assumptions:

   - The Gold King Mine load (mass per unit time) would have the same percent attenuation as was observed during the sampling event:

     $$\text{Load Attenuation} = (\dot{M}_{CC48} + \dot{M}_{A68} + \dot{M}_{M34} - \dot{M}_{A72}) / (\dot{M}_{CC48} + \dot{M}_{A68} + \dot{M}_{M34})$$

     Where $\dot{M}$ represents contaminant load and subscripts represent the three major contributors to A72: Cement Creek (CC48), Animas River upstream of Cement Creek (A68), and Mineral Creek (M34).

   - The predicted concentration at A72 for each non-runoff sampling event was calculated as:

     $$C^{P}_{A72} = [C_{A72}Q_{A72} + (1\text{-Load Attenuation}) * C^{PR}_{GKM}(Q^{PR}_{GKM}\text{-}Q_{GKM}] / (Q_{A72} + Q_{GKM})$$

     Where C^{P}_{A72} is the predicted concentration at A72 with the addition of the extra Gold King Mine discharge, C is the observed concentration, and Q is the measured flow. Subscripts indicate monitoring locations A72 or Gold King Mine (GKM). Q^{PR}_{GKM} and C^{PR}_{GKM} represent the average post-release (August 15-September 11) Gold King Mine flow and concentrations, respectively.

   Historic and predicted concentrations are shown on Table 6. Column 8 shows the median predicted concentration for times with A72 flow similar to August 2015 flow. Column 9 shows the median predicted concentration for times with lowest historic flows.

2) A72 metal concentrations were also estimated with the assumption that the August 2015 metal loads at A72 would remain constant while the flow at A72 varied by month. The average monthly and 25th percentile flows from USGS gauging station 09359020 were used to predict the monthly concentrations at A72. The results are shown on Table 7. This method may overestimate concentrations at A72 because loading from other sources in the system (as seen at A68 and M34) may be reduced through the lowest flow months.

8.0 PREDICTED CONCENTRATIONS AT BAKERS BRIDGE

Four methods were used to estimate concentrations at Bakers Bridge, approximately 30 miles downstream of A72:

A. Assume predicted A72 concentrations were reduced by the August 2015 Bakers Bridge:A72 concentration ratio.

   a. $C^P_{BB} = C^P_{A72} * [C_{BB, Aug2015}/C_{A72, Aug2015}]$

   b. Where BB is Bakers Bridge and C^P indicates predicted concentrations. The results are shown in column 6 of Table 8.

B. Same as Method 1 but for the lowest flow conditions (Table 5). The results are shown on in column 7 of Table 8.

C. Assume constant load at A72 (worst case in February) and dilute the concentration using the ratio of flow at USGS Gauging Station 09359020 (Animas River below Silverton) and 09359500 (Animas River at Tall Timbers). The results are shown on Table 9.

   a. $C_{BB} = C_{A72} * [Q_{A72} /Q_{TT}]$

   Where Q represents flow and TT represents the Tall Timbers gauging station.

   This method is conservative because water entering the Animas River between Tall Timbers and Bakers Bridge, approximately 9 miles south, dilute the metal concentrations. Additionally, metals attenuation is expected between A72 and Bakers Bridge, partially due to precipitation from the pH change. During August 2015 the average pH at A72 was 6.1 and the average pH at Bakers Bridge was 7.7.

D. Assume constant load at Bakers Bridge (using Tall Timbers flow rates to represent Bakers Bridge both for calculating August 2015 load and for allocating to various months of the year). Table 10 presents the results.

9.0 HAZARD QUOTIENTS

Hazard quotients (HQs) were calculated using each of the predicted concentrations for Bakers Bridge. The HQs were calculated using Colorado Water Quality Regulations (WQS) Table Value Standards (TVS) (Colorado Department of Public Health and Environment Water Quality Control Commission, Regulation Number 31, The Basic Standards and Methodologies for Surface Water, 5CCR1002-31). The average winter hardness of 175 was used for hardness-dependent TVS at Bakers Bridge. The TVS equations and the values calculated using hardness 175 mg/L are shown on Table 11.

Species-specific HQs were calculated for Bakers Bridge using toxicity thresholds presented in Appendix 5 of the Final Draft Baseline Ecological Risk Assessment, Upper Animas Mining District, San Juan County, Colorado. April 2015. Appendix 5 (Draft, April 14, 2015). The toxicity thresholds were calculated using the average winter

hardness of 175 mg/L. The toxicity threshold equations and the toxicity threshold calculated at hardness 175 mg/L are shown on Table 11.

HQs are found on Tables 12 and 13. Species-specific chronic cadmium and copper toxicity thresholds were not available for brook trout. Use of the acute cadmium and copper toxicity thresholds would result in conservative conclusions.

TABLE 1
Animas River downstream of Silverton (A72) Metal Concentrations (micrograms per liter)
August 11-31, 2015

	Average	Median	Minimum	Maximum
Cadmium, Dissolved	1.93	1.9	1.6	2.2
Cadmium, Total	1.97	2	1.6	2.3
Copper, Dissolved	15.9	16	12	20
Copper, Total	58.9	59.5	48	72
Iron, Dissolved	732	750	520	950
Iron, Total	3030	2950	2100	4600
Zinc, Dissolved	586	600	420	730
Zinc, Total	609	585	460	760

Daily samples collected from 8/11/15 to 8/31/2015; Gold King Mine release was 8/5/2015.

TABLE 2
Gold King Mine Discharge (CC06) Metal Concentrations (micrograms per liter)
August 15-September 3, 2015

	Average	Median	Minimum	Maximum
Cadmium, Dissolved	74.6	78	60	83
Cadmium, Total	71.5	76.5	55	85
Copper, Dissolved	5890	5850	4600	6800
Copper, Total	5780	5800	4600	6300
Iron, Dissolved	111,000	105,000	93,000	150,000
Iron, Total	131,000	135,000	120,000	140,000
Zinc, Dissolved	24,600	24,500	20,000	28,000
Zinc, Total	24,300	24,500	20,000	28,000

TABLE 3
August 2015 versus Historic (2009-2014) Metal Concentrations
Animas River downstream of Silverton (A72)

		Cadmium		Copper		Iron		Zinc	
		Dissolved	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**	**Dissolved**	**Total**
Current	Average	1.93	1.97	**15.9**	**58.9**	733	3030	586	609
	Median	1.9	2	**16**	**59.5**	750	2950	600	585
	Min	1.6	1.6	12	**48**	520	2100	420	460
	Max	2.2	2.3	20	**72**	950	4600	730	760
All Historic	Average	1.61	1.70	12.0	25.2	1383	3409	578	618
	Median	1.68	1.7	7.61	24.2	1420	3290	590	637
	Min	0.6	0.8	3.02	6.4	199	787	52.2	221
	Max	2.9	2.9	36.9	47.5	3250	7710	1170	1150
Runoff Historic	Average	0.94	1.13	5.50	20.3	444	2038	301	346
	Median	0.87	0.91	5.00	16.5	343	1300	270	305
	Min	0.6	0.8	3.25	6.4	199	787	133	221
	Max	1.80	2.60	8.81	47.5	809	5300	588	685
Non-Runoff Historic	Average	2.04	2.06	15.7	28.1	1876	4192	747	791
	Median	1.835	1.92	13.4	26.2	1910	4155	739	728
	Min	1.19	1.11	3.02	10.3	443	1340	52.2	391
	Max	2.9	2.9	36.9	46.7	3250	7710	1170	1150

Runoff: May through July Non-runoff: August through April

Note that the August 2015 dissolved and total cadmium, iron, and zinc concentrations are within the range of historic values. The August 2015 dissolved copper concentrations exceed the non-runoff average and median concentrations, but the maximum historic concentration was greater than August 2015 concentrations. The August 2015 total copper concentrations exceed any of the historic concentrations.

TABLE 4
Percent of Flow and Metals Load from Sources to Animas River downstream of Silverton (A72)
Current (August 29-31, 2015) and Historic Non-Runoff

		Animas River upstream of Cement Creek (A68)		Cement Creek (CC48)		Mineral Creek upstream of Animas River (M34)		Animas River downstream of Silverton (A72)	
		Current	**Historic**	**Current**	**Historic**	**Current**	**Historic**	**Current**	**Historic**
Flow	cfs	54.6	43	20	16	55	38	133	102
	% of Total	42%	43%	15%	8%	42%	46%	103%	103%
Cadmium	Dissolved	20%	30%	67%	54%	13%	15%	102%	102%
	Total	20%	31%	67%	53%	13%	15%	100%	103%
Copper	Dissolved	2%	6%	96%	84%	1%	9%	35%	56%
	Total	4%	11%	89%	78%	7%	14%	97%	103%
Iron	Dissolved	0%	1%	55%	59%	45%	40%	53%	61%
	Total	2%	2%	59%	55%	39%	43%	95%	91%
Zinc	Dissolved	17%	26%	75%	61%	8%	12%	99%	103%
	Total	18%	26%	74%	62%	9%	11%	101%	102%

Historic values used for this comparison are 2009-2014 non-runoff (August through April) medians.
Note that the A72 percentages are greater than 100% if the flow/load at A72 is greater than the sum of the flow/load from A68, CC48 and M34.

TABLE 5
Animas River pH – Upstream to Downstream, Historic and Current

Historic pH (Upstream to Downstream)				Current pH (Upstream to Downstream)	
Location	**5/14/2013**	**5/5/2014**	**9/14/2014**	**Location**	**9/2015**
Upstream of Cement Creek (A68)	7.4	7.1	7.7	Animas at Silverton (A68)	7.67
Downstream of Silverton (A72)	6.9	6.3	7.0	Animas Downstream of Silverton (A72)	6.78
Upstream of Elk Creek (A73)	7.3	7.2	7.2	Animas at Elk Park (GKM20)	7.19
Elk Creek (A73EC)	7.4	--	7.3	Mile Marker 486 (GKM305)	7.21
Downstream of Elk Creek (A73B)	7.3	7.2	7.2	Mile Marker 482; Near Cascade Creek (GKM304)	7.42
Molas Creek (A73MC)	8.0	--	--	North side of Cascade Siding; Mile Marker 479 (GKM303)	7.33
Upstream of Cascade Creek (A75D)	7.5	--	6.9	Left Spur; Mile Marker 477.81 (GKM302)	7.34
Cascade Creek (A75CC)	8.0	7.9	7.3	Tall Timbers; Mile Marker 475.3 (GKM301)	7.59
Downstream of Cascade Creek (A75B)	7.4	7.3	6.9	Downstream of Mile Marker 475; 100 feet upstream of Tank Creek (GKM300)	7.52
Bakers Bridge	7.6	7.6	7.6	Tacoma Power Plant; Mile Marker 472.28 (GKM299)	7.63
				Bakers Bridge	7.69

TABLE 6
Predicted Concentrations at A72
(Concentrations in micrograms per liter)

		Current	Historic				Predicted with increased GKM discharge			
		(1) August 11-31, 2015	(2) Historic Median	(3) Historic Maximum	(4) Historic Similar Flow Median	(5) Historic Lowest Flow Median	(6) Median for August to April (Non-Runoff)	(7) Predicted with increased GKM discharge – Range for August to April	(8) Predicted with increased GKM discharge – Similar Flow	(9) Predicted with increased GKM discharge – Lowest Flow
Cadmium	Dissolved	1.9	1.8	2.9	1.8	2.6	2.6	1.5-3.7	1.9	3.6
	Total	2	2.0	2.9	1.8	2.7	2.4	1.4-3.7	2.0	3.5
Copper	Dissolved	16	14.6	36.9	10.7	35.5	40.4	11.8-111	23.8	106
	Total	59.5	33.6	47.5	22.4	40.1	78.2	31.1-119	54.4	115
Iron	Dissolved	750	1650	3250	1030	2760	2160	738-4570	1380	3820
	Total	2950	3750	7710	2420	6290	4470	1760-9360	2980	7740
Zinc	Dissolved	600	711	1170	558	1120	900	475-1440	675	1400
	Total	585	693	1150	609	1110	915	499-1430	686	1420

GKM Gold King Mine
gpm gallons per minute

(1) 8/11-31/2015 median concentrations
Columns (2) through (5) show historic concentrations. Primary EPA sampling events from 2009-2014 were used unless otherwise specified.
(2) Historic median concentrations (2009-2014)
(3) Historic maximum from all 2009-2014 EPA data including mini-sipper data.
(4) Median concentrations for 2009-2014 sampling events with similar A72 flow conditions to August 2015. Events with flows from 131 to 250 cfs were used (August 2011, April 2010, October 2011, and September 2014). Minisipper data were not used.
(5) Historic median for 2009-2014 sampling events with the lowest A72 flow conditions. Events with flows from 57 to 68 cfs were used (November 2009, February and March 2010, March 2011).

Columns (6) through (9) show predicted concentrations with added Gold King Mine flow. Assumptions include event-specific attenuation of contaminants and event-specific difference between current and historic GKM flow. When GKM flow was not measured due to inclement weather, the average of the two closest sample events was used.

(6) This column shows the average predicted concentrations for all non-runoff sampling events from 2009-2014.
(7) This column shows the range of predicted concentrations for all non-runoff sampling events from 2009-2014.
(8) This column shows the average results for the events described for column (4), similar flow conditions to August/September 2015
(9) This column shows the median results for the events described for column (5), lowest flow conditions, and indicates what might happen during low flow conditions at A72.

TABLE 7
A72 Estimated Monthly Concentrations assuming Median August 2015 A72 Load
(Concentrations in micrograms per liter)

MEDIAN LOAD WITH AVERAGE MONTHLY FLOW													
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cadmium	Dissolved	5.0	5.4	4.1	1.7	0.4	0.3	0.7	1.4	1.7	2.1	3.5	4.6
	Total	5.0	5.4	4.1	1.7	0.4	0.3	0.7	1.4	1.7	2.1	3.5	4.6
Copper	Dissolved	39.0	42.4	32.4	13.6	3.5	2.4	5.5	11.1	13.7	16.2	27.6	36.2
	Total	149	162	124	52.0	13.2	9.2	21.0	42.5	52.2	61.9	106	138
Iron	Dissolved	1850	2010	1530	643	163	114	260	527	647	766	1310	1710
	Total	7350	7980	6090	2560	649	454	1033	2100	2570	3050	5200	6810
Zinc	Dissolved	1460	1590	1210	508	129	90	205	416	511	605	1030	1350
	Total	1600	1740	1330	558	142	99	226	457	561	665	1140	1490
MEDIAN LOAD WITH 25TH PERCENTILE MONTHLY FLOW													
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Cadmium	Dissolved	5.6	6.5	5.3	2.2	0.5	0.4	1.4	2.5	2.4	3.0	4.0	4.9
	Total	5.6	6.5	5.3	2.2	0.5	0.4	1.4	2.6	2.4	3.0	4.0	4.9
Copper	Dissolved	43.9	51.3	41.8	17.5	3.9	3.3	10.9	20.1	18.8	23.8	31.2	38.3
	Total	168	196	160	67.0	15.0	12.7	41.7	76.7	71.9	91.0	119	147
Iron	Dissolved	2080	2430	1980	830	186	157	516	950	890	1127	1480	1810
	Total	8270	9650	7870	3300	739	625	2050	3780	3540	4480	5870	7210
Zinc	Dissolved	1640	1920	1560	656	147	124	408	750	703	890	1170	1430
	Total	1810	2110	1720	720	161	136	448	824	772	978	1280	1580

Concentrations calculated by taking median monthly load at A72 during August 11-31, 2015 and dividing by the mean or 25th percentile monthly flow at USGS Gauging Station 09359020.

TABLE 8
Predicted Concentrations at Bakers Bridge – Methods A and B
(Concentrations in micrograms per liter)

		Current	**Historic (2009-2014)**	**Predicted**				
		(1) August 11-31, 2015	(2) Historic Non-Runoff Median	(3) Median for August to April (Non-Runoff)	(4) Predicted with increased GKM discharge – Minimum	(5) Predicted with increased GKM discharge – Maximum	(6) Predicted with increased GKM discharge – Similar Flow **METHOD A**	(7) Predicted with increased GKM discharge – Lowest Flow **METHOD B**
Cadmium	Dissolved	0.64	0.444	0.84	0.49	1.20	0.62	1.17
	Total	0.78	0.470	0.91	0.53	1.40	0.76	1.33
Copper	Dissolved	2.75	1.89	7.37	2.15	20.2	4.34	19.3
	Total	18	2.82	24.2	9.63	36.9	16.8	35.6
Iron	Dissolved	17	50	28.7	9.80	60.7	18.3	50.7
	Total	825	317	1335	525	2794	890	2311
Zinc	Dissolved	135	131	207	109	330	155	321
	Total	220	216	326	178	510	245	506

Note: Concentrations extrapolated from A72 predicted concentrations using August 2015 ratio of A72:Bakers Bridge concentrations.

(1) 8/11-31/2015 median concentrations
(2) Historic median non-runoff (August to April) concentrations (2009-2014)

Columns (3) through (7) show predicted concentrations with added Gold King Mine flow. Assumptions include event-specific attenuation of contaminants and event-specific difference between current and historic GKM flow. When GKM flow was not measured due to inclement weather, the average of the two closest sample events was used.

(3) This column shows the average predicted concentrations for all non-runoff sampling events from 2009-2014.
(4) This column shows the minimum of predicted concentrations for all non-runoff sampling events from 2009-2014.
(5) This column shows the maximum of predicted concentrations for all non-runoff sampling events from 2009-2014.
(6) This column shows the average results for the events described for column (4), similar flow conditions to August/September 2015
(7) This column shows the median results for the events described for column (5), lowest flow conditions, and indicates what might happen during low flow conditions at A72.

TABLE 9
Predicted Bakers Bridge Metals Concentrations – Method C
Constant A72 Load (August 2015); Monthly Flow Ratios from Tall Timbers Gauging Station
(Concentrations in micrograms per liter)

		August 2015	Historic Lowest Flow Non-Runoff* Median	Predicted (February) if A72 Load Remains Constant – Average Water Year	Predicted (February) if A72 Load Remains Constant – 25th Percentile Water Year	Predicted August
Cadmium	Dissolved	0.64	0.444	3.1	3.7	0.9
	Total	0.78	0.470	3.1	3.7	0.9
Copper	Dissolved	2.75	1.89	24.3	29.5	6.8
	Total	18	2.82	93.0	113	25.9
Iron	Dissolved	17	50	1154	1400	321
	Total	825	317	4583	5540	1280
Zinc	Dissolved	135	131	913	1100	253
	Total	220	216	999	1210	278

Assumes dilution from A72 flows to Tall Timbers Flows. Does not account for metals attenuation in the Animas River.

TABLE 10
Predicted Bakers Bridge Metals Concentrations – Method D
Constant Bakers Bridge Load (August 2015); Monthly Flow Ratios from Tall Timbers Gauging Station
(Concentrations in micrograms per liter)

		August 2015	Historic Non-Runoff* Median	Predicted (February) if Bakers Bridge Load Remains Constant – Average Water Year	Predicted (February) if Bakers Bridge Load Remains Constant – 25th Percentile Water Year	Predicted August
Cadmium	Dissolved	0.64	0.444	1.90	2.22	0.53
	Total	0.78	0.470	2.23	2.61	0.62
Copper	Dissolved	2.75	1.89	8.05	9.41	2.24
	Total	18	2.82	53.7	62.7	14.9
Iron	Dissolved	17	50	27.4	32.0	7.61
	Total	825	317	2440	2850	679
Zinc	Dissolved	135	131	400	467	111
	Total	220	216	599	700	167

Predicted August concentrations are less than average August 2015 concentrations because August 2015 had lower than average flow at Tall Timbers. These numbers should be considered very rough estimates because the Tall Timbers flow data is incomplete and because Bakers Bridge is located 9 miles downstream of Tall Timbers.

TABLE 11
Reference Values used in Hazard Quotient Calculations
(All concentrations in micrograms per liter)

Metal[a]		Formula	Calculated at Hardness 175 mg/L
Colorado Table Value Standards[b]			
Cadmium	acute (trout)	$(1.136672-[(\ln \text{hardness})*(0.041838)])*e^{(0.9151[\ln \text{hardness})]-3.6236)}$	2.77
	chronic	$(1.101672-[(\ln \text{hardness})*(0.041838)])*e^{(0.7998[\ln \text{hardness})]-4.4451)}$	0.65
Copper	acute	$e^{(.9422[\ln \text{hardness}] - 1.7408)}$	22.8
	chronic	$e^{(.8545[\ln \text{hardness}] - 1.7428)}$	14.4
Iron (total)	chronic	1000	1000
Zinc	acute	$0.978*e^{(0.9094[\ln \text{hardness}] + 0.9095)}$	266
	chronic	$0.986*e^{(0.9094[\ln \text{hardness}] + 0.6235)}$	202
Species Specific Toxicity Threshold - Brook Trout[c]			
Cadmium	acute	$e^{(0.8103[\ln \text{hardness}] - 3.026313167)}$	3.19
	chronic	Not available	NA
Copper	acute	$e^{(1.109[\ln \text{hardness}] - 1.215207193)}$	91.2
	chronic	Not available	NA
Zinc	acute	$e^{(1.1712[\ln \text{hardness}] + 2.014642264)}$	3177
	chronic	$e^{(1.1712[\ln \text{hardness}] + 1.859649082)}$	2721
Species Specific Toxicity Threshold - Brown Trout[c]			
Cadmium	acute	$e^{(0.8103[\ln \text{hardness}] - 2.977125910)}$	3.35
	chronic	$e^{(0.8103[\ln \text{hardness}] - 3.177000834)}$	2.74
Copper	acute	$e^{(1.109[\ln \text{hardness}] - 1.445451847)}$	72.4
	chronic	$e^{(1.109[\ln \text{hardness}] - 1.528275300)}$	66.7
Zinc	acute	$e^{(1.1712[\ln \text{hardness}] + 1.063378861)}$	1227
	chronic	$e^{(1.1712[\ln \text{hardness}] + 1.266107227)}$	1502

a Dissolved fraction except as noted (total recoverable iron)

b Colorado Department of Public Health and Environment Water Quality Control Commission, Regulation Number 31, The Basic Standards and Methodologies for Surface Water, 5CCR1002-31). The average winter hardness of 175 was used for hardness-dependent TVS at Bakers Bridge.

c Species-specific HQs were calculated for Bakers Bridge using toxicity thresholds presented in Appendix 5 of the Final Draft Baseline Ecological Risk Assessment, Upper Animas Mining District, San Juan County, Colorado. April 2015. Appendix 5.

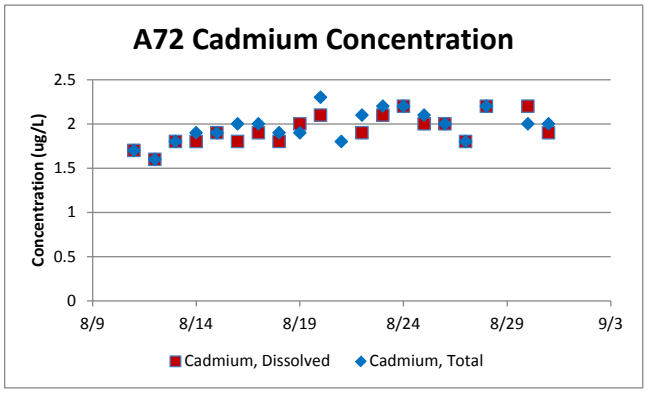
TABLE 12
Colorado Table Value Standards and Species-Specific Hazard Quotients
Predicted at Bakers Bridge Using Historic Data with Increased Gold King Mine Discharge

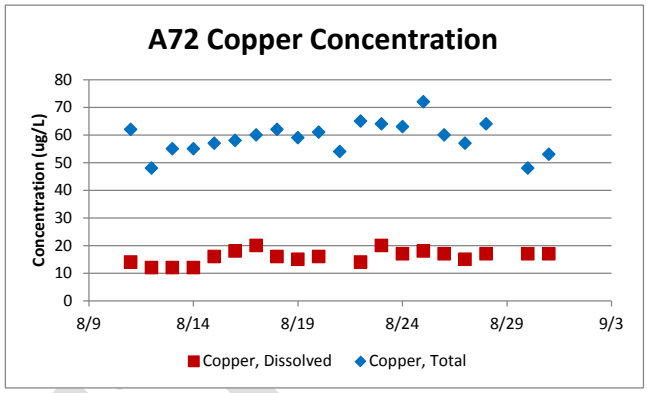
		August 11-31, 2015	Historic Non-Runoff Median	Predicted Median for August to April (Non-Runoff)	Predicted Minimum August to April (Non-Runoff)	Predicted Maximum August to April (Non-Runoff)	Predicted with increased GKM discharge – Similar Flow METHOD A	Predicted with increased GKM discharge – Lowest Flow METHOD B
Colorado Aquatic Life Table Standard Value - Acute								
Cadmium	Dissolved	0.23	0.16	0.30	0.18	0.43	0.22	0.42
Copper	Dissolved	0.12	0.08	0.32	0.09	0.89	0.19	0.85
Zinc	Dissolved	0.51	0.49	0.78	0.41	1.24	0.58	1.21
Colorado Aquatic Life Table Standard Value - Chronic								
Cadmium	Dissolved	0.99	0.69	1.30	0.75	1.85	0.95	1.80
Copper	Dissolved	0.19	0.13	0.51	0.15	1.40	0.30	1.34
Iron	Total	0.83	0.32	1.33	0.53	2.79	0.89	2.31
Zinc	Dissolved	0.67	0.65	1.02	0.54	1.64	0.77	1.59
Acute Brook Trout								
Cadmium	Dissolved	0.20	0.14	0.26	0.15	0.38	0.19	0.37
Copper	Dissolved	0.03	0.02	0.08	0.02	0.22	0.05	0.21
Zinc	Dissolved	0.04	0.04	0.07	0.03	0.10	0.05	0.10
Chronic Brook Trout								
Zinc	Dissolved	0.05	0.05	0.08	0.04	0.12	0.06	0.12
Acute Brown Trout								
Cadmium	Dissolved	0.19	0.13	0.25	0.15	0.36	0.18	0.35
Copper	Dissolved	0.04	0.03	0.10	0.03	0.28	0.06	0.27
Zinc	Dissolved	0.11	0.11	0.17	0.09	0.27	0.13	0.26
Chronic Brown Trout								
Cadmium	Dissolved	0.23	0.16	0.31	0.18	0.44	0.22	0.43
Copper	Dissolved	0.04	0.03	0.11	0.03	0.30	0.07	0.29
Zinc	Dissolved	0.09	0.09	0.14	0.07	0.22	0.10	0.21

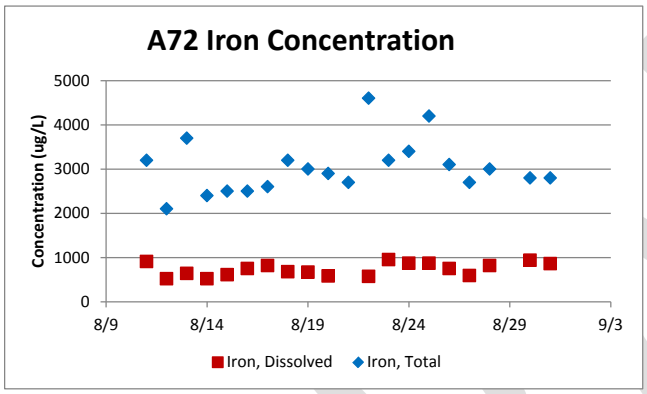
TABLE 13
Colorado Table Value Standards and Species-Specific Hazard Quotients
Predicted at Bakers Bridge Assuming Constant Load at A72 or Bakers Bridge

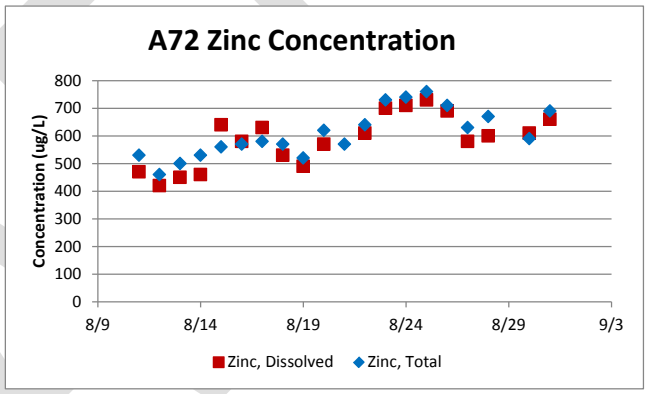
		August 11-31, 2015	Historic Lowest Flow Non-Runoff* Median	Predicted (February) if A72 Load Remains Constant – Average Water Year METHOD C	Predicted (February) if A72 Load Remains Constant – 25th Percentile Water Year METHOD C	Predicted (February) if Bakers Bridge Load Remains Constant – Average Water Year METHOD D	Predicted (February) if Bakers Bridge Load Remains Constant – 25th Percentile Water Year METHOD D
TVS Acute							
Cadmium	Dissolved	0.23	0.16	1.12	1.33	0.69	0.80
Copper	Dissolved	0.12	0.08	1.07	1.30	0.35	0.41
Zinc	Dissolved	0.51	0.49	3.43	4.13	1.50	1.75
TVS Chronic							
Cadmium	Dissolved	0.99	0.69	4.79	5.72	2.94	3.43
Copper	Dissolved	0.19	0.13	1.68	2.04	0.56	0.65
Iron	Total	0.83	0.32	4.58	5.54	2.44	2.85
Zinc	Dissolved	0.67	0.65	4.53	5.46	1.98	2.32
Brook Trout Acute							
Cadmium	Dissolved	0.20	0.14	0.97	1.16	0.60	0.70
Copper	Dissolved	0.03	0.02	0.27	0.32	0.09	0.10
Zinc	Dissolved	0.04	0.04	0.29	0.35	0.13	0.15
Brook Trout Chronic							
Zinc	Dissolved	0.05	0.05	0.34	0.40	0.15	0.17
Brown Trout Acute							
Cadmium	Dissolved	0.19	0.13	0.93	1.11	0.57	0.66
Copper	Dissolved	0.04	0.03	0.34	0.41	0.11	0.13
Zinc	Dissolved	0.11	0.11	0.74	0.90	0.33	0.38
Brown Trout Chronic							
Cadmium	Dissolved	0.23	0.16	1.13	1.35	0.69	0.81
Copper	Dissolved	0.04	0.03	0.36	0.44	0.12	0.14
Zinc	Dissolved	0.09	0.09	0.61	0.73	0.27	0.31

GRAPH SET 1
Animas River downstream of Silverton (A72) Metal Concentrations
August 11-31, 2015

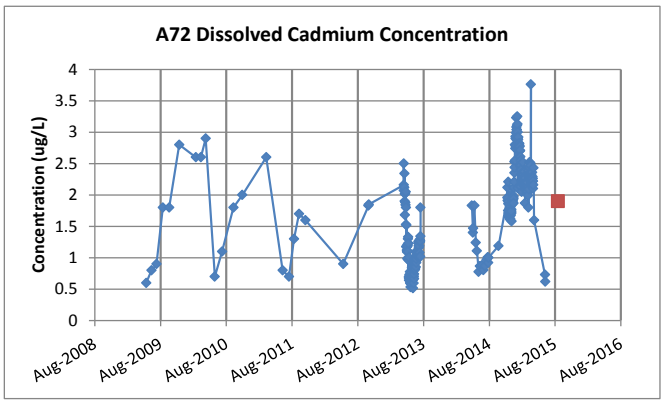


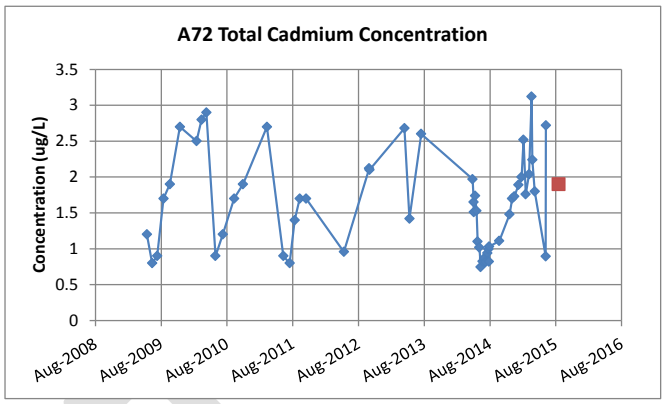


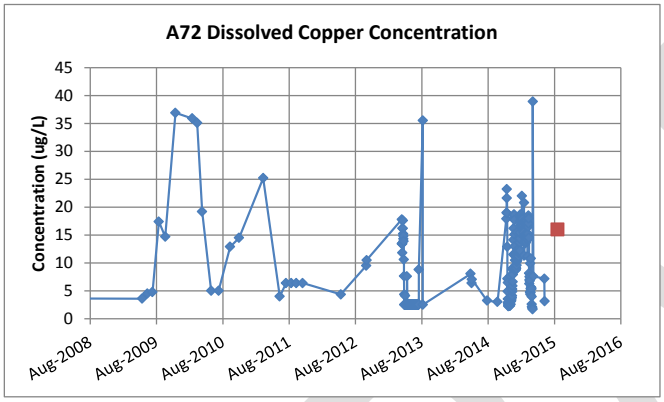


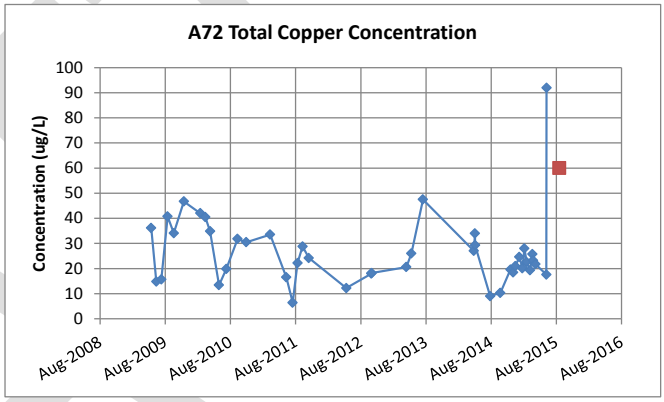


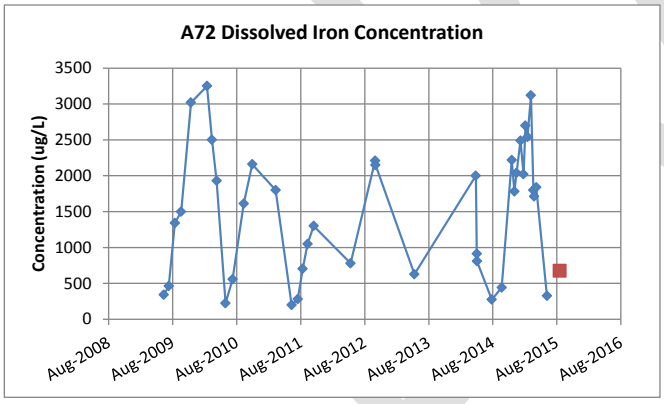
GRAPH SET 2
Animas River downstream of Silverton (A72)
Metal Concentrations – August 2015 vs. Historic

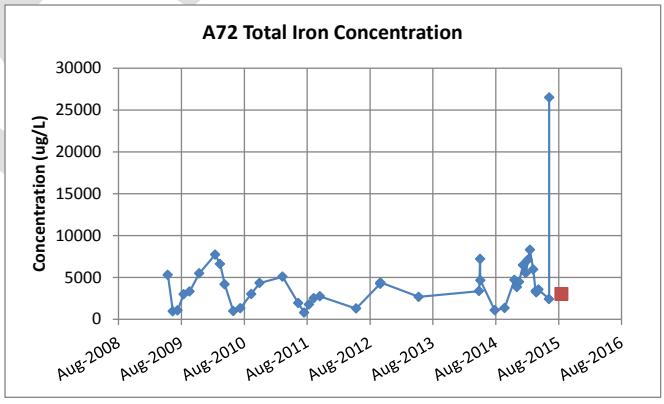


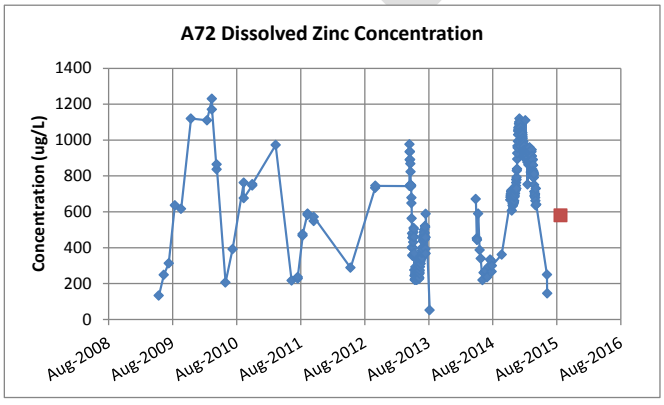


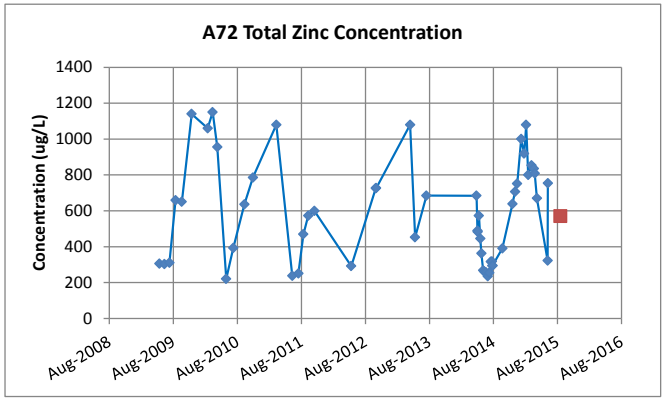




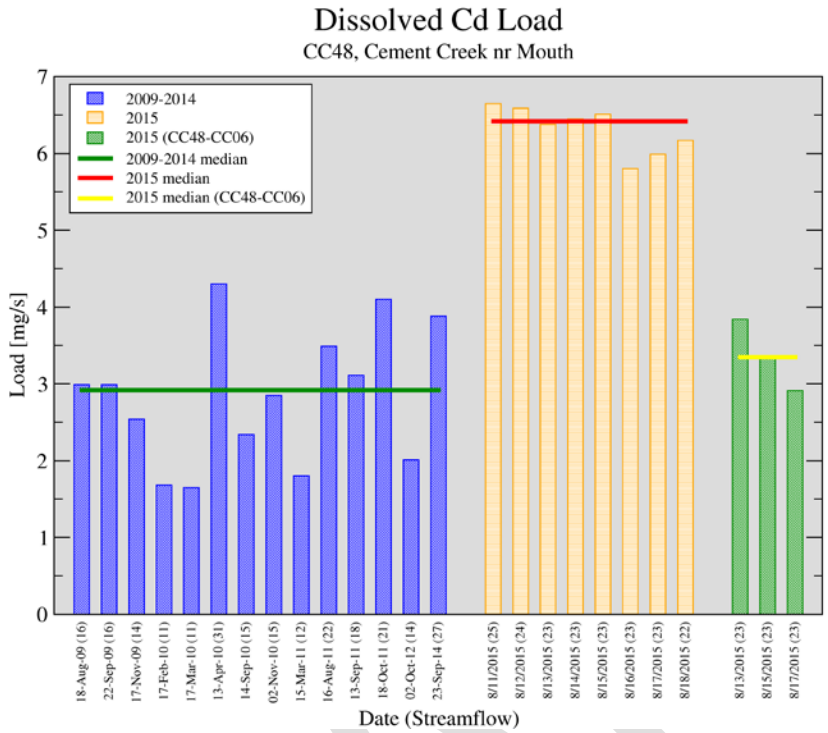


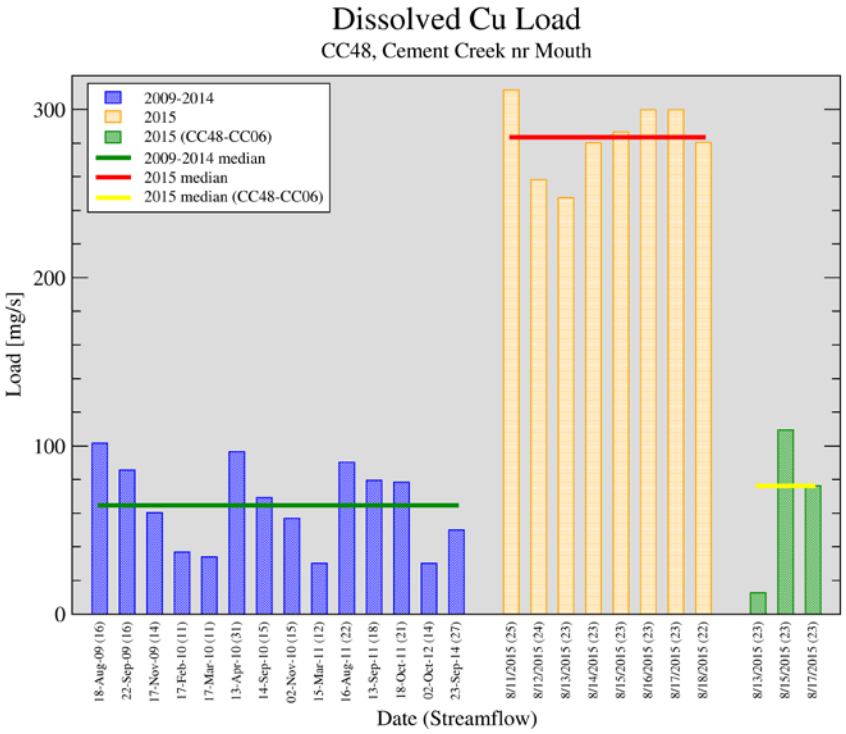






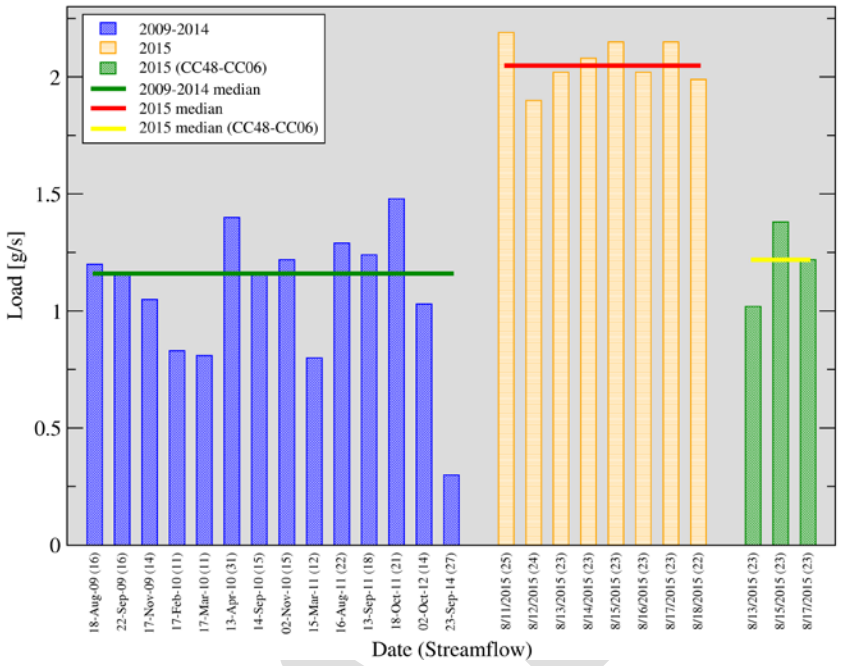
Graph Set 3
Cement Creek Load Comparisons
(Prepared by USGS)



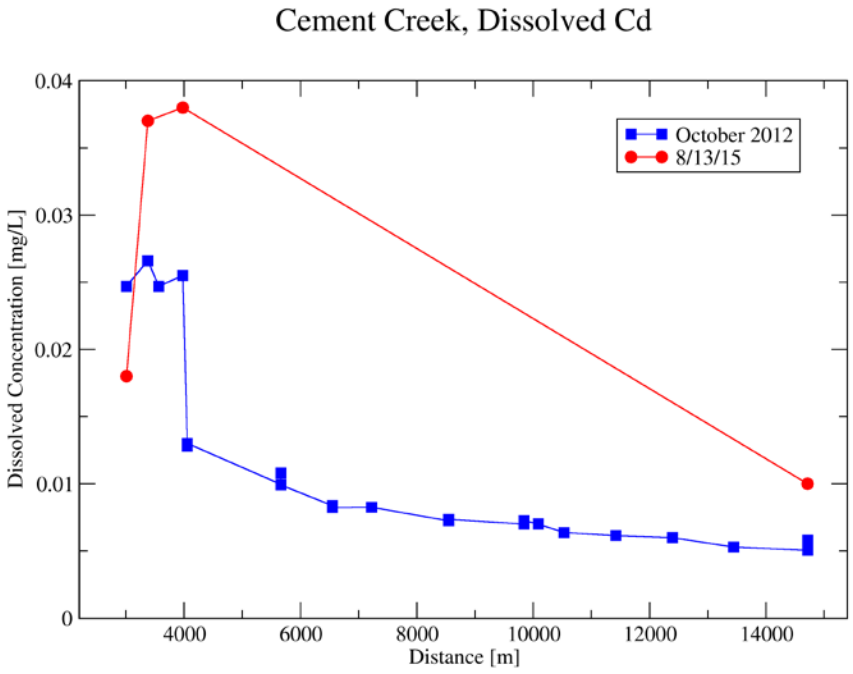


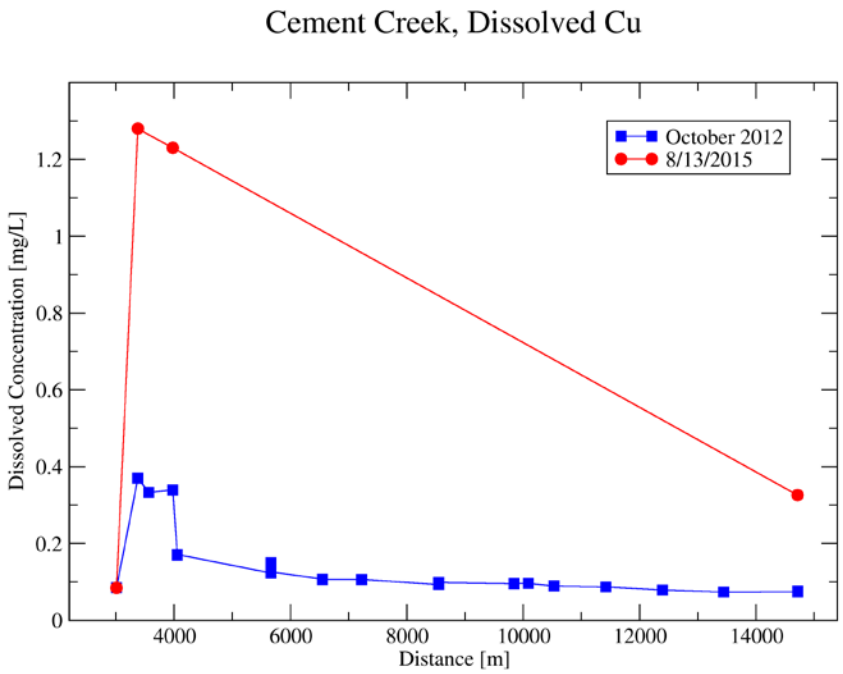
Dissolved Zn Load

CC48, Cement Creek nr Mouth

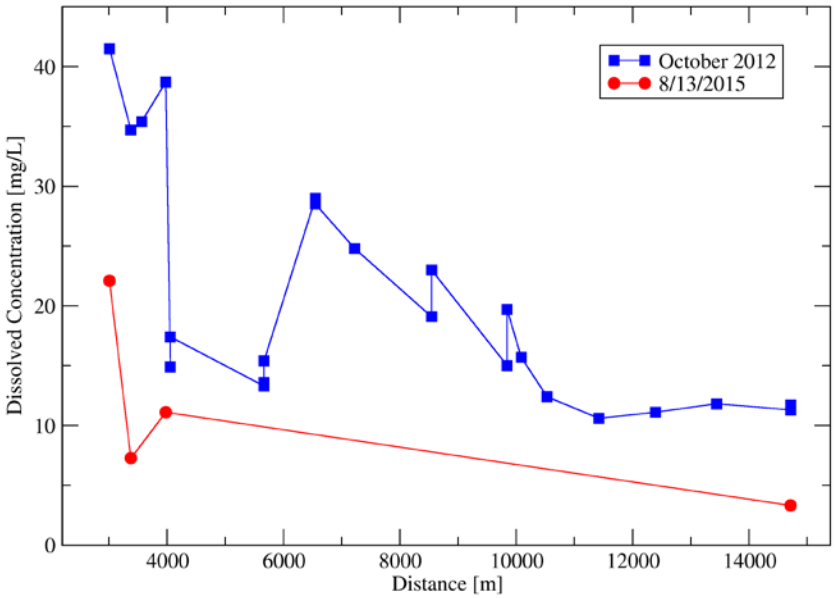


Graph Set 4
Cement Creek Contaminant Concentrations along Cement Creek, October 2015 vs 8/13/2015
(Prepared by USGS)

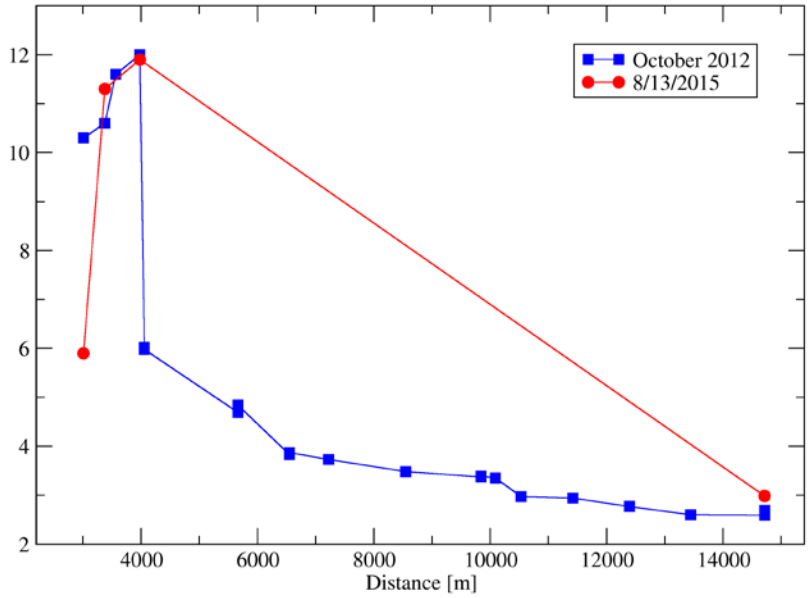




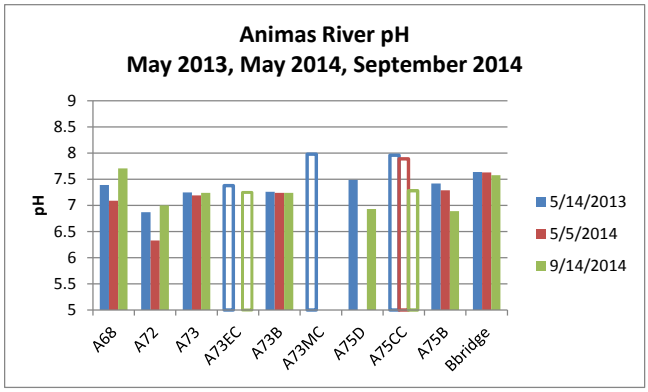
Cement Creek, Dissolved Iron

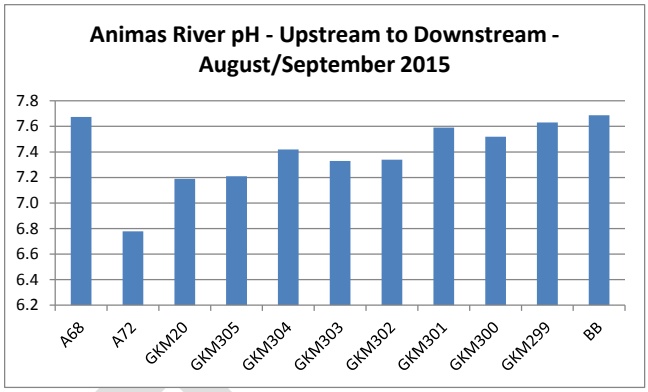


Cement Creek, Dissolved Zn

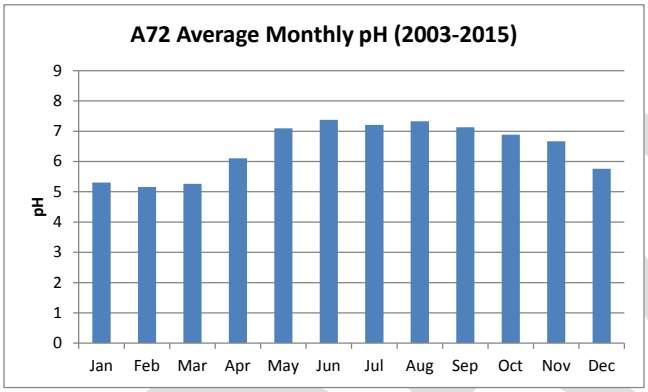


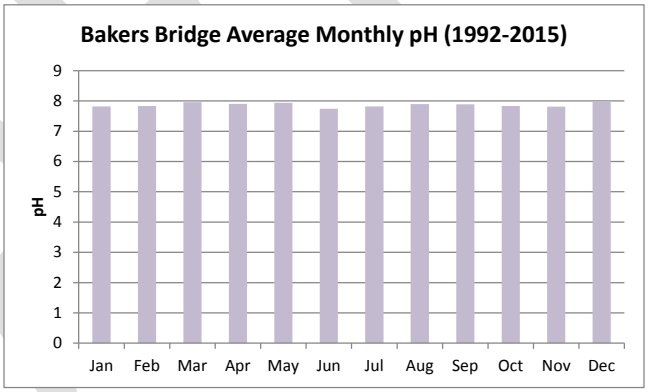
GRAPH SET 5
Animas River pH – Upstream to Downstream
(See Table 5 for location descriptions)



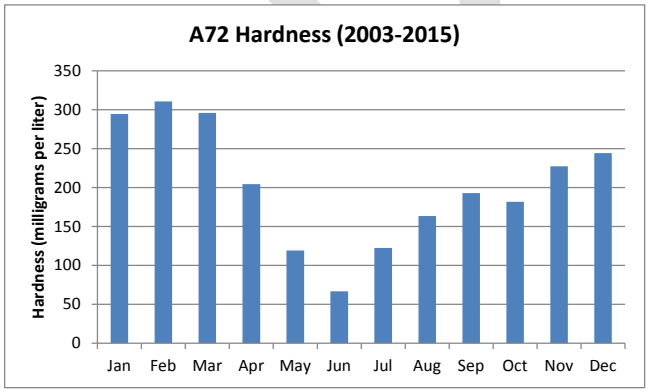


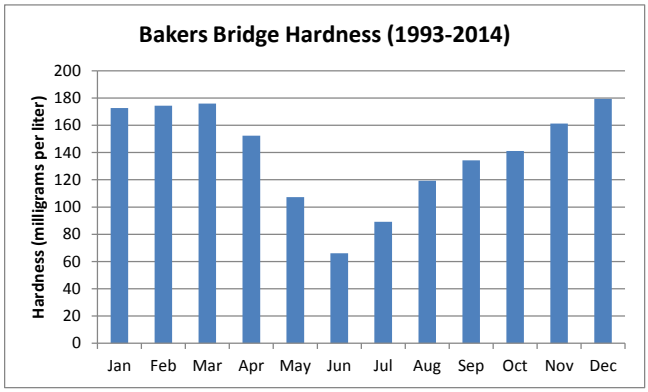
GRAPH SET 6
Average Monthly pH at A72 and Bakers Bridge





GRAPH SET 7
Average Monthly Hardness at A72 and Bakers Bridge





From:	Way, Steven
To:	Sisk, Richard
Subject:	Fwd: Water Treatment Decision - draft tech memo
Date:	Wednesday, September 30, 2015 3:39:20 PM
Attachments:	A72 and Bakers Bridge Concentrations - DRAFT 09-19-2015.docx ATT00001.htm

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Admin Record document

FYI - START memo (draft) water quality predictions for low flow and associated hazard quotients.

EPA (Way, Wall,) USGS , and Weston participated in developing this.

Steve

Sent from my iPhone

Begin forwarded message:

From: (b) (4) >
To: "Way, Steven" <way.steven@epa.gov>
Subject: Water Treatment Decision

See attached.